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DEVELOPMENT AND TESTING OF A FIBRE OPTIC DATA SYSTEM FOR MARINE TRANSPORTATION

VOLUME 1: MAIN REPORT

by

G.A.J. Smith
J.W. Snow
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FOCAL MARINE LIMITED

April 1987

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17. Abstract

The purpose of this project was to draft standards for the shipboard use of fibre optics. To gain the necessary experience, a pilot data and video system was designed and installed on an icebreaker.

The method of measuring system performance was through digital bit error rate, optical power and video quality. Power and reflectometer checks before and after sea trials also served to show environmental dependencies.

The results showed no correlation between optical performance and environmental parameters (high and low temperatures, vibrations) or cable type. Certain weaknesses were highlighted in component design and selection.

In conclusion, the fibre optic system performed well. A set of draft standards was produced which can serve as a guide to allow marine shipping interests to take full advantage of the benefits of this technology.

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17. Résumé

L'objectif de cette recherche a été de définir des normes concernant les utilisations marines des câbles à fibres optiques. Afin d'acquérir l'expérience nécessaire, un système pilote de transmission de données vidéo-alphanumériques a été conçu, réalisé et installé à bord d'un brise-glace.

La méthode de mesurage des performances a été triple: taux d'erreurs dans la transmission des données numériques, puissance optique à la réception et qualité de la visualisation. Des contrôles de puissance et de réflectivité ont été faits avant et après les essais en mer, aux fins de mettre en évidence l'influence des facteurs d'environnement.

Les résultats ne dégagent aucune corrélation entre paramètres optiques et paramètres d'environnement: écarts de température, niveaux vibratoires, pas plus qu'entre différents types de câbles. Certaines faiblesses ont été mises en évidence au niveau de la conception et de la sélection des composants.

L'appareillage à fibres optiques a bien fonctionné. Un ensemble de normes provisoires a été rédigé; il pourra servir de guide aux transporteurs maritimes souhaitant tirer parti de cette technologie.

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
BER	Bit Error Rate
BERTS	Bit Error Rate Test Set
CCG	Canadian Coast Guard
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CSA	Canadian Standards Association
CSI	Canadian Steamship Inspectors
CSMA/CD	Carrier Sense Multiple Access with Collision Detect
dB	deciBel
DOD	Department of Defense, U.S. Government
EIA	Electronic Industries Association
EMI	Electromagnetic Interference
ENV	Environmental
g	acceleration due to gravity (9.81 m/s^2)
GI	Graded Index
GTE	GTE Lenkurt Incorporated
HD	Heavy Duty
Hz	Hertz
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
JRC	Japan Radio Corporation
LBR	Lower Boiler Room
LD	Light Duty
LED	Light Emitting Diode
MCR	Machinery Control Room
NA	Numerical Aperture
NASA	National Aeronautics and Space Administration
nm	nano metre (1×10^{-9} metre)
NSRFC	Nova Scotia Research Foundation Corporation
OFTI	Optical Fibers Technology Incorporated
OTDR	Optical Time Domain Reflectometer/Reflectometry
PLL	Phase Locked Loop
PRNG	Pseudo-Random Number Generator
QA	Quality Assurance
RX	Receiver (also Rx)
SDH	Scientific Data Highway
SMA	Subminiature Type A
S/N	Serial Number
SNAME	Society of Naval Architects and Marine Engineers
SNR	Signal to Noise Ratio
TC	Transport Canada
TSC	Transmissive Star Coupler
TX	Transmitter (also Tx)
um	micrometer (1×10^{-6} metre)
WDM	Wavelength Division Multiplexer/Dumultiplexer

1.0 INTRODUCTION

This report is submitted to the Transportation Development Center (TDC) in completion of contract Serial No. ISC84-00404, DSS File No. 07SC.T8200-4-4544 entitled "Development and Testing of A Fibre Optic Data System for Marine Transportation (UP-F-122), dated September 6, 1984.

1.1 Purpose

The main purpose of the project was to propose draft standards for the shipboard use of fibre optic technology. With this objective in mind, a pilot fibre optic data and video system was installed on the CCGS Louis S.St. Laurent. The purposes of the installation were to:

(a) Provide vital experience in the selection, installation, testing and maintenance of fibre optic cables at sea.

(b) Provide a tested prototype of a system which is intended for fitting in the Polar 8 icebreakers.

(c) Provide a set of draft standards for the non-military use of fibre optic cables and components at sea.

(d) Place Canada in the forefront of the use of fibre optics in shipbuilding.

1.2 Background

Fibre optics provides an ideal method for moving data at high speeds in an extremely noisy (high interference) environment. These conditions are typical onboard ships and especially so in icebreakers. The preliminary specifications for the proposed Polar 8 include a fibre optic data bus system.

There is no doubt that the use of fibres in non-military vessels will increase as the improved availability of components results in decreasing costs. However, non-military standards are not available for the marine usage of fibre optic data links and cabling. To avoid degradation of safety at sea, which could be the result of hasty adoption of a new technology, a program was needed to systematically establish standards and increase the general technical awareness about fibre optics in marine applications.

Transport Canada recognized the need for fibre optic shipboard standards and sponsored a study which led to an Unsolicited Proposal (UP-F-122) for "Development of a Fibre Optic Data System for Marine Transportation" dated February, 1984, modified June 1984. The contract was awarded in September, 1984.

1.3 Report Contents

This report is in two volumes. Volume I is the main report; Volume II contains the draft proposed standards. The Summary is bound separately and designated TP8526E.

As seen in the Table of Contents, the report reviews briefly the background of the project, the methodology and the system configuration. It then presents the test results, standards, conclusions and recommendations. Also provided is a section (7.0) which discusses the general experience gained in applying fibre optics to the shipboard environment.

Many preliminary reports were submitted during the course of the project, as identified by the various tasks in the Project Plan. The content of these interim reports has been captured and updated in the appropriate sections of this report.

The drawing package is described in section 3.4.

2.0 METHODOLOGY

In keeping with the major objectives of this project the methodology has been designed to support the development of standards for the shipboard use of fibre optics. The information on which to base the standards is based on a pilot installation and on other sources of data.

2.1 Pilot Installation

A pilot fibre optic system was designed and installed aboard a Canadian Coast Guard vessel. The schematic is given in figure 2.1. The design of this system incorporated a variety of fibre optic components and component types. It was through a detailed analysis of the performance of this system over a one year test period that some of the information required to draft standards was obtained. The pilot system contained both a digital and an analog subsystem. It was the performance of the digital channel which was the primary measure of system suitability for shipboard applications; inherently, a digital system is more amenable to quantitative analysis than is an analog system.

2.2 Other Sources

In addition to the pilot system, information required to draft standards was obtained from a variety of other sources. These sources included national and international standards writing organizations, manufacturers of optical fibre, cable and devices, and users. Military sources such as the U.S. Department of Defense were also consulted for information regarding fibre optic standards and specifications.

In summary, information was gleaned both from non-shipboard fibre optic standards and non-fibre optic shipboard standards, combined with common sense and judgment gained through experience on a variety of other projects.

2.3 Choice of Vessel

It was decided that the pilot installation should be on an icebreaker, in order to subject the system to the most demanding shipboard vibration, icing and thermal cycling conditions. This exposure was desirable in order to enable the most rigorous and diverse testing possible, giving the best basis for the establishment of standards.

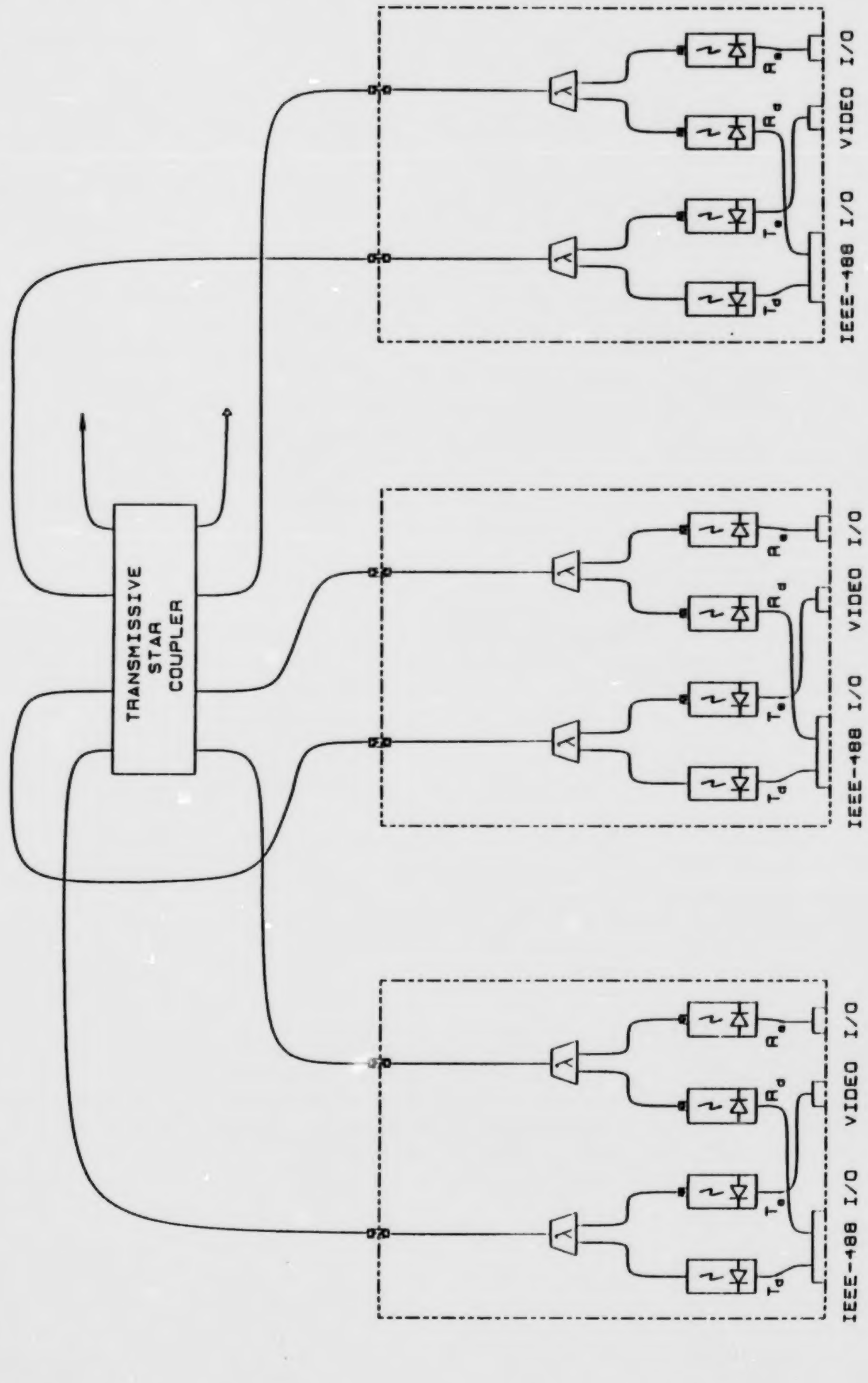

TRANSMISSIVE STAR COUPLER
λ
T_d
T_e
R_d
R_e
IEEE-488 I/O
VIDEO I/O

Figure 2.1 Data Highway Configuration

A Dartmouth based vessel was preferred for logistical reasons. Of the available vessels, the Louis S. St. Laurent was seen as the best choice for the following reasons:

- maximum potential for system longevity
- the turbo electric propulsion system provides the widest range of temperature and humidity conditions for cable exposure
- the ship's activities planned for the next two years accommodated system installation and testing.

2.4 Review of Schedule

The schedule summary is given in figure 2.2. It is seen that the project was conducted in five phases, two of which were in parallel.

Work proceeded on schedule until the mid-point of the installation (Phase D) when a fire occurred, damaging one of the main propulsion motors. This was in December, 1985. The associated delay in the ship's sailing schedule required a contract amendment to extend the completion date to March, 1987 in order to obtain a useful sea trial.

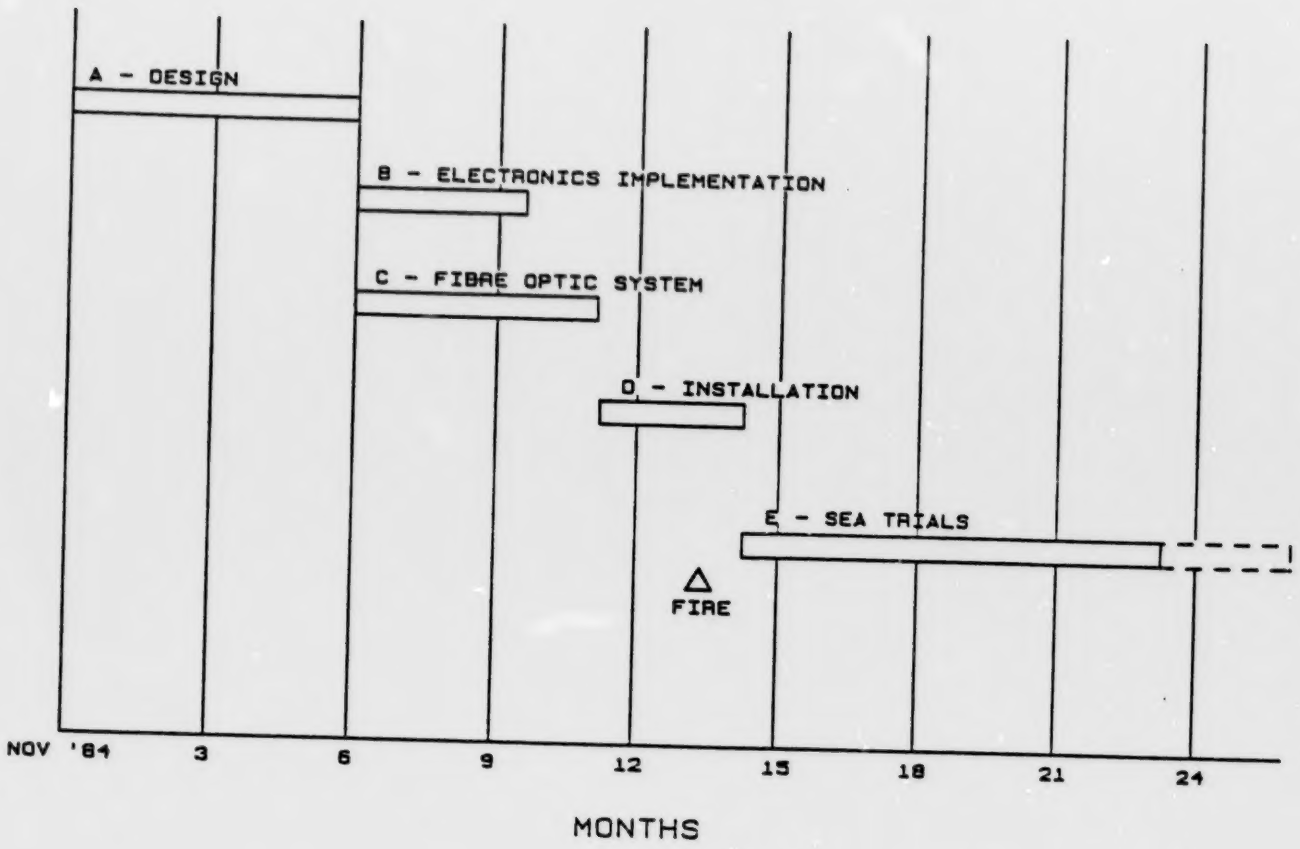


Figure 2.2 Schedule Summary

3.0 SYSTEM OVERVIEW

3.1 Topology

Figure 3.1 shows three common fibre optic topologies, namely the bus, loop and star. The bus is simple but prone to system failure caused by a single node failure. The receivers need large dynamic range, as each one sees a different flux level.

The loop permits more flexibility than the bus in terms of fault tolerance, but has the same dynamic range limitation.

The selected topology for the pilot system was a planar transmissive star supporting 3 nodes in the initial installation (see Figure 2.1). The system design allows for expansion to 10 nodes based on the flux budget analysis. A brief discussion of the merits of this topology choice for the intended shipboard application follows.

The star topology is totally passive and hence inherently reliable. Because each node is individually linked to the central distribution point, individual node failures do not affect the rest of the network. In addition, the star design yields a very small loss deviation between any two nodes, and therefore eliminates the requirement for a receiver with a large dynamice range.

The planar nature of the star also means that additional nodes can be added by simply changing the coupler and running a cable to the new node. Although limited in nodal capacity as compared to an active design, the star is quite suited to shipboard applications for which a requirement for greater than 20 nodes would be rare.

Having selected the star topology it was necessary to choose between the reflective and transmissive types. Cabling costs are kept to a minimum with a reflective star topology because the reflective star supports bidirectional data transmission over a single fibre. However a transmissive star (unidirectional) was used in the pilot system to capitalize on the higher flux budget, at the expense of needing a separate fibre for each direction. This fibre capacity was available in the specified cables.

3.2 Node Location

Node site selection, cable routing and star location were chosen to permit a useful demonstration of shipboard digital and analog transmission over fibre optic cable and to complement the system test requirement and thereby facilitate and development of standards.

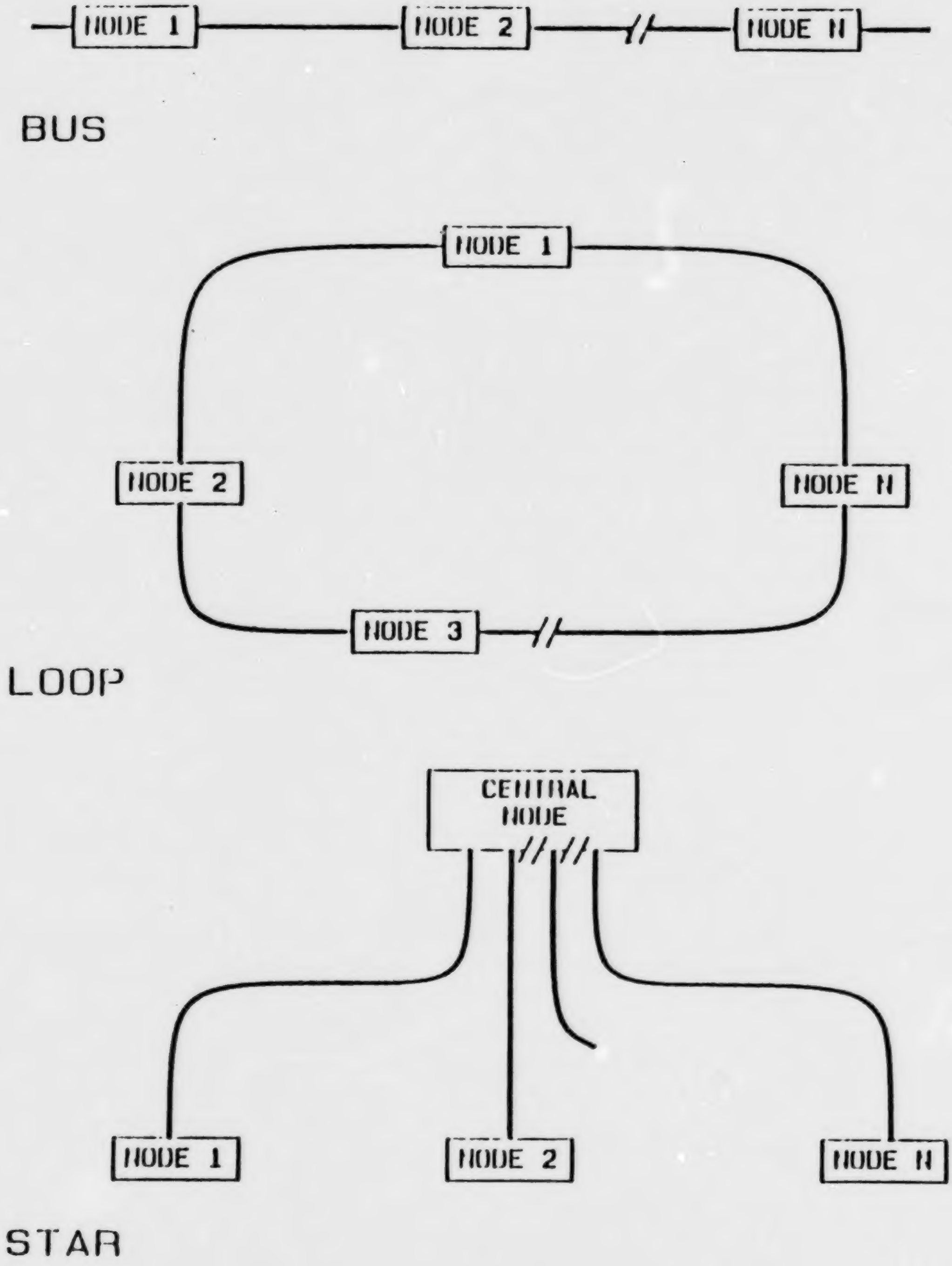

NODE 1
NODE 2
NODE N
BUS
NODE 1
NODE 2
NODE N
NODE 3
LOOP
CENTRAL NODE
NODE 1
NODE 2
NODE N
STAR

Figure 3.1 Topologies

The three nodes were located in the machinery control room (MCR), the lower boiler room (LBR) and on the bridge.

The star couplers (one for each cable) were co-located with the machinery control room node. The fibre links provided exposure to the environment by appearing on deck for a portion of the run. The link to the lower boiler room was routed to ensure operation in extremes of temperature, humidity, vibration and EMI. These two cable routes were termed "ENV" and "EMI" respectively.

3.3 Modes of Operation

The pilot system took two basic forms. One form was an IEEE-488 compatible, three node data highway and the second form was a two route data logger.

3.3.1 Data Highway Format

The data highway configuration of the pilot system as demonstrated during the bench test phase of the work consisted of three access nodes linked together by fibre optic cable through a transmissive star coupler. This configuration was shown in Figure 2.1, "Data Highway Configuration". It exceeds the contractual requirement for a two-station bus with a tap-off connection.

Each of the nodes has an IEEE-488 interface as well as a video input and output terminal. Although both the digital and analog signals are broadcast simultaneously on the same fibre, they are kept separate by operating at different wavelengths. The use of wavelength division demultiplexers ensures that each wavelength signal is received at the correct receiver. Figure 3.2 shows the general physical arrangement.

Digital data access to the data highway is controlled via a packet broadcast technique called Carrier Sense Multiple Access with Collision Detect (CSMA/CD) as implemented by the data highway nodes. Parallel data from the IEEE-488 input is converted to a serial format for transmission on the highway and, at the destination, is converted back to IEEE-488 format for output from the node to the device.

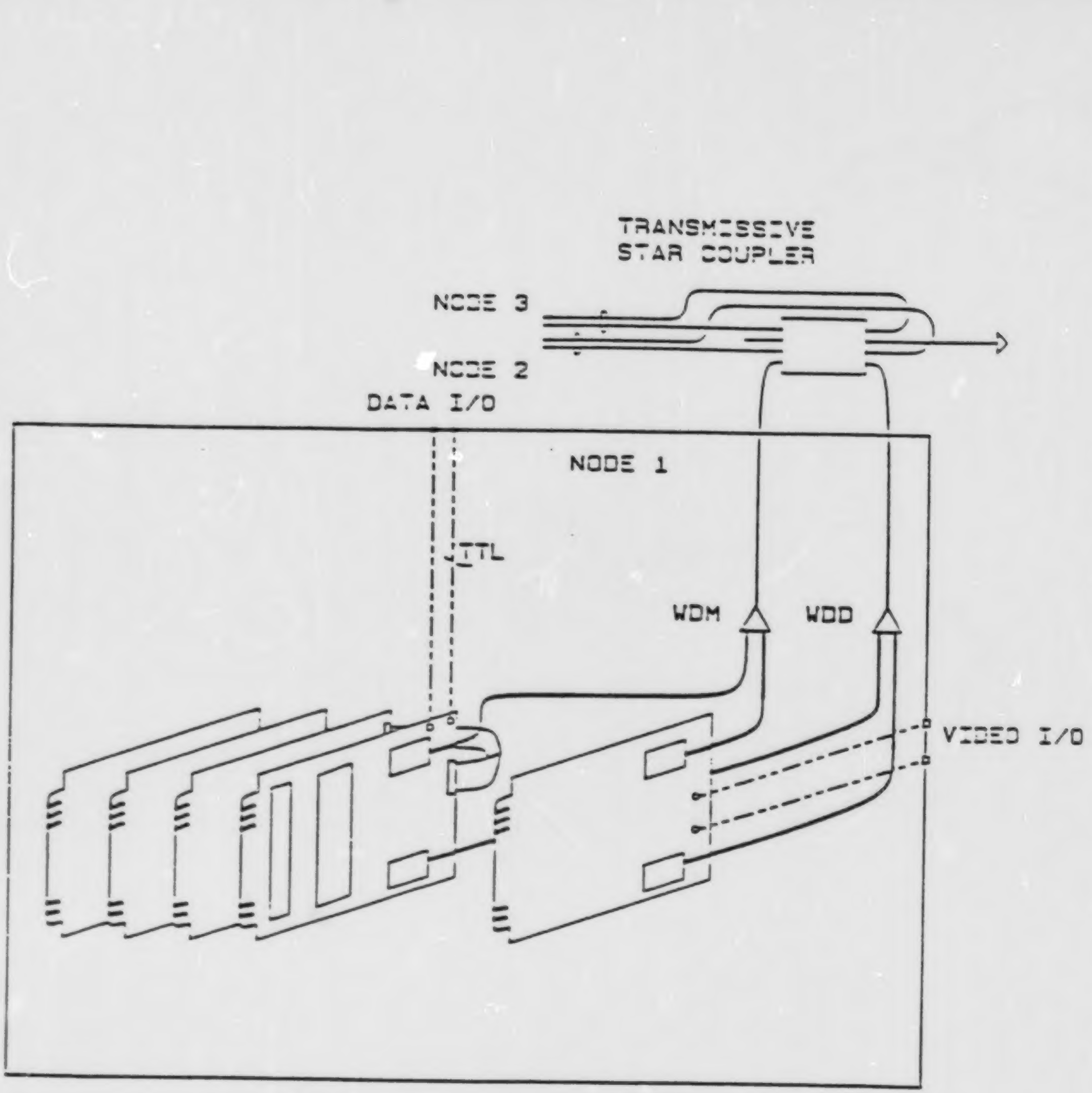

TRANSMISSIVE
STAR COUPLER
NODE 3
NODE 2
DATA I/O
NODE 1
TTL
WDM
WDD
VIDEO I/O

Figure 3.2 General Node Arrangement

This technique allows any station access to the network whenever the broadcast medium is idle. In the event of a message collision, collision detection halts transmission and retransmission is scheduled according to station priority. Data integrity is ensured via CRC-16 error detection and an acknowledgement type protocol.

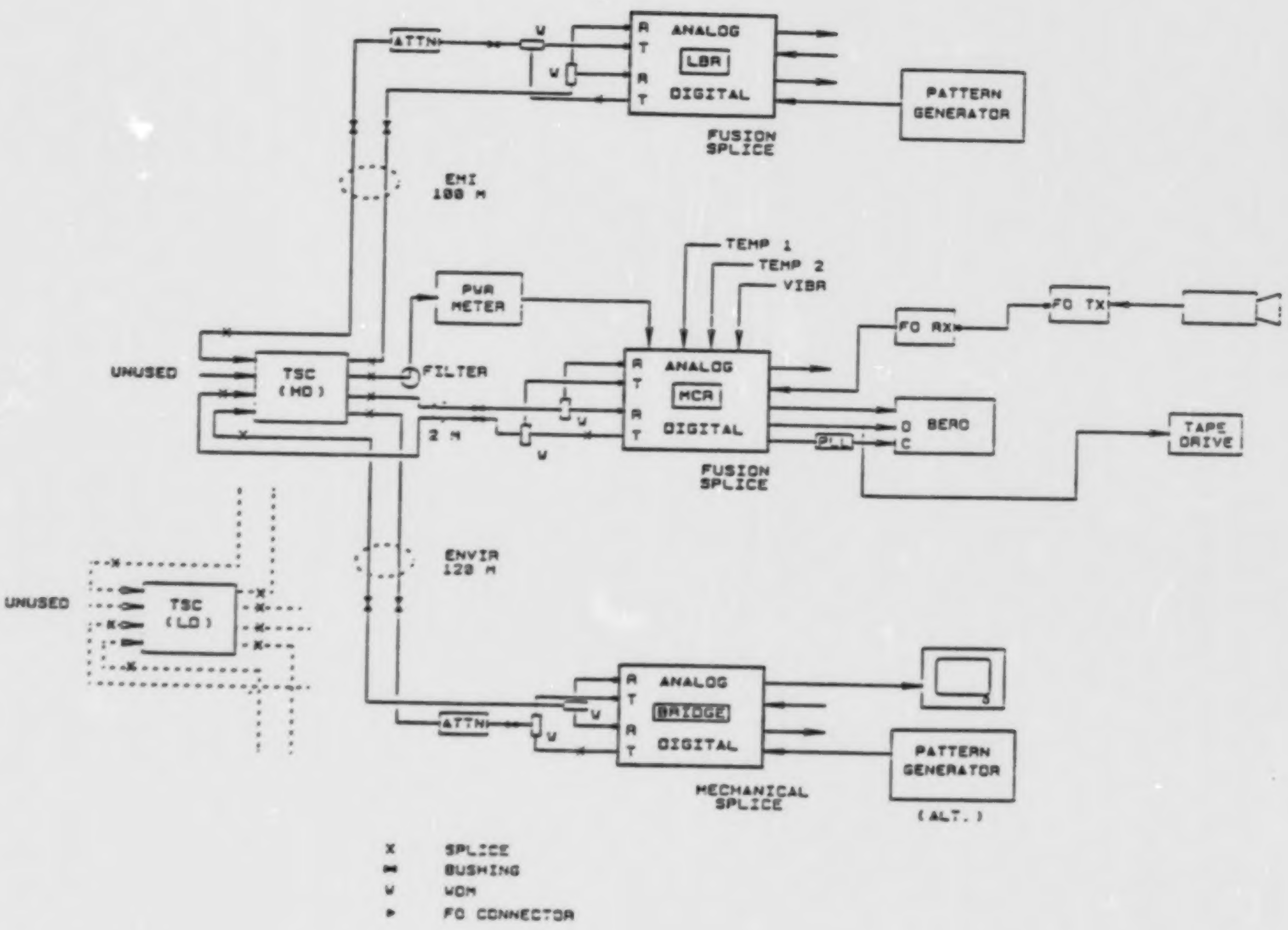
CSMA/CD is well suited to shipboard applications, ie. where a passive station connection is desirable and where certain data is likely to require priority access to the medium. CSMA/CD has been proven to be highly efficient for environments with relatively short propagation delay, as is the case for fibre optic links.

3.3.2 Data Logger Format

The same data highway system was used during the sea trials as a data logger system in point-to-point operation. This required a separate software package.

When configured in the data logging format, one node (MCR) acted as the data logger controller for the digital system. Figure 3.3 "Data Logger Configuration" shows how the system was configured for data logging operation. The pattern generator was located either at the lower boiler room (LBR) node or the bridge node to select either the electromagnetic interference (EMI) route or the environmental route (ENV) respectively. The system flux was controlled with a varible optical attenuator, one of which was located at each of the remote nodes. The active cable, light duty (LD) or heavy duty (HD), was selected at an SMA bushing bracket in each node.

The data logger controller recorded the output from three environmental sensors, a system optical power monitor and the output and status of the bit error rate test set (BERTS) on a data storage tape. Each record stored on the tape was provided with a time/date stamp from the controller. Log books kept by the system operators provided information regarding the active route selected, the cable in use and the nominal flux level.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DIGITAL
PATTERN GENERATOR
FUSION SPLICE
EMI 100 M
TEMP 1
TEMP 2
VIBR
PWR METER
UNUSED
TSC (HD)
FILTER
2 M
W
W
R
T
R
T
ANALOG
MCR
DIGITAL
FUSION SPLICE
FO RX
FO TX
D
C
BERD
PLL
TAPE DRIVE
ENVIR 120 M
UNUSED
TSC (LD)
ATTN
W
W
R
T
R
T
ANALOG
BRIDGE
DIGITAL
MECHANICAL SPLICE
PATTERN GENERATOR
(ALT.)
X SPLICE
BUSHING
W WDM
FO CONNECTOR

Figure 3.3 Data Logger Configuration

Independent of the data logging operation but concurrent with it was the operation of the video system. Video data was broadcast by the MCR node to all three nodes but was only monitored at the bridge node. The video was broadcast on the same cable selected for the digital transmission. Bridge personnel kept a log of the performance of the video system.

3.4 Drawing Package

A complete drawing package was developed during the first phase of the project, showing the "as-designed" state. The package was then updated after the installation phase to show the system "as delivered". At each time a submission was made.

A Bill of Materials (BOM) accompanies the drawing package. It serves the same purpose as a parts list, and also serves as the basis for the cost model, having a space for standard labour hours and material costs.

The drawing package is series 8468, reflecting the company-assigned job number. There are three types of drawing: assembly, detail and specification control. The latter type was used to control each bought-out assembly for which acceptance tests were needed.

The drawings were computer-generated on a system known as VERSA-CAD.

4.0 COMPONENT SELECTION

Component selection was driven by a number of factors including the topology and the testing rationale. In a few instances, availability of supply was the decisive factor. Where components were available from a number of suppliers, more than one supplier was used so that a wider sample of components could be evaluated. Such was the case with the SMA type connectors. Table 4.1 lists the major component suppliers.

4.1 Data Highway Nodes

The project specifications required the interconnection of IEEE-488 devices via the data highway. Also, the optical data highway was required to be an off-the-shelf system, possibly with custom developed optical boards integrated into it. The integration of the optics with the data highway required an intimate knowledge of the data highway and a close working relationship with the supplier.

Candidates that were considered are:

- Seimac Data Highway
- Hewlett Packard 37203A HPIB Extender
- Fujikura Limited Extender Model FFL.MD.01
- IBM PC Net
- Ungermann-Bass Net One Ethernet System

Of these devices, only the Seimac Data Highway allowed easy access to the station units which was needed in order to implement the required functions in the demonstration project. It was the only commercially available product to provide true IEEE-488 support for both nests and stations. It uses the STD-BUS standard for modular microcomputer design, making it relatively easy to add the optical STD cards (for digital and video channels) thereby achieving the interface to the fibre medium.

The PC Net and Net One systems were not originally intended for use with IEEE-488 and their suitability was uncertain.

The Extenders did not fulfill the requirement for an optical "tap" (i.e. a data bus).

The Seimac units were selected because they met all requirements. The close association of Seimac with Focal Marine Limited allowed for a close relationship during integration of the optical assemblies. Also, Seimac has had its data highway installed on a ship since 1982, demonstrating its reliability in the shipboard environment.

Table 4.1 Major Suppliers

CABLE	-	SIECOR (LD)
	-	WHITMOR WAVEGUIDE (HD)
TX, RX	-	MERET (820,1300 NM)
	-	OPTELECOM (820)
COUPLERS	-	CANSTAR
WDM/WDD	-	JDS OPTICS
ELECTRONICS	-	SEIMAC
CONNECTORS	-	AMPHENOL
	-	OFTI
MECH. SPLICE	-	G.T.E.
ENCLOSURES	-	HAMMOND
	-	ITT VALTEC

4.2 Fibre Type

Multimode fibre was selected over singlemode fibre so that device (connector, coupler and splice) costs could be kept low. Multimode fibre was able to provide adequate bandwidth and attenuation characteristics for shipboard requirements.

The chosen fibre size, 100/140 um was selected because of the relatively low alignment requirements when compared with the smaller 50/125 um fibre. Also, due to its use by the military, this size fibre is expected to remain available for some time.

The chosen construction type (refractive index profile) was graded index which has less dispersion and is more commonly used than step index multimode fibre. Pricing for step and graded index multimode fibres is comparable.

Glass fibre was selected over plastic fibre due to its lower attenuation.

4.3 Cable

Many cable suppliers were solicited to bid on the cable requriements. Six bids were received; none was from a Canadian supplier, who generally are geared up for steady production of long-haul telemetry cable (mostly singlemode).

Whitmor Waveguide and Siecor were chosen as the cable suppliers. Whitmor was able to supply the custom made heavy duty (HD) cable in a short run production at a reasonable price. Siecor was able to supply an off-the-shelf cable which met the requirements of the light duty (LD) cable.

4.4 Transmitters and Receivers

There were three different types of transmitter and receiver sets required. These included the video transmitters and receivers for the data highway nodes, the digital transmitters and receivers for the data highway nodes, and the video link from the camera to the MCR node.

Optelecom was chosen as the supplier of the short wavelength video link from the camera because of the ability to build the transmitter into the camera and demonstrated reliability in severe environments. By modifying the package and power supply circuit, the transmitter was able to be fitted inside the camera enclosure. Also, the receiver was small and easy to accommodate inside the MCR node enclosure.

Meret Inc. was the only supplier that could provide STD mounted video transmitters and receivers with the SNR and flux requirements of the planned system. Other manufacturers whose products were considered for this application included Optelecom, Artel Communications, Focom Systems and LeCroy. None of these suppliers could supply off-the-shelf transmitters and receivers with the flux required so that some custom engineering would have been required. In all cases, a custom STD card was required to accommodate the transmitters and receivers.

It was decided to avoid laser diode transmitters due to high cost, relatively short life and the need for careful temperature control relative to LED's. Meret Inc. was the only manufacturer who could supply long wavelength transmitters and receivers with the flux margins required for the planned system. A subsequent change in the design from a reflective star coupler (RSC) to a transmissive star coupler (TSC) relaxed the flux requirements for both the short and the long wavelength systems but by that time the commitment to the Meret devices had been made.

In the two years since the devices were specified, many new and improved transmitters and receivers have been offered.

The demanding nature of the flux budget was a result of the system complexity (couplers, multiplexers, connectors, etc), which was required to evaluate as many devices as possible in regard to the preparation of standards. Operational installations could be designed with lower flux budgets.

4.5 Star Couplers

Both the initially intended reflective star coupler (RSC) and the ultimately used transmissive star coupler (TSC) were purchased from Canstar Communications. These devices were able to meet the system design requirements and were supplied by a Canadian manufacturer.

4.6 Wavelength Division Multiplexers

JDS Optics Inc. of Ottawa was identified as a Canadian supplier of a good quality wavelength division multiplexer (WDM) which adequately met the requirements of the system design in terms of optical qualities, physical properties and fibre type.

Similar multiplexers were considered from Siecor, ADC, Northern Telecom and American Photonics.

4.7 Connectors

The type of fibre connector selected for use within the system was the SMA type connector. This connector type was chosen for a number of reasons including its widespread acceptance within the fibre optic industry and its availability from a number of suppliers in a variety of materials and qualities. Connectors were obtained from Amphenol and OFTI. Amphenol connectors were chosen because they have become an industry standard and OFTI connectors were chosen because of their advertised compatibility with the Amphenol connectors and lower cost.

4.8 Mechanical Splices

At the time that the system was designed, there was not a large selection of suitable mechanical splices to choose from. The only mechanical splice which had widespread use was the GTE elastomeric splice. It also had the lowest insertion loss.

There have been significant improvements in the selection and quality of mechanical splices since the original splice type was specified. GTE have redesigned their splice packs to provide a more reliable device and other manufacturers have come out with good quality, low loss splices.

4.9 Enclosures

There were two enclosure requirements, one for the data highway nodes and one for the transmissive star couplers. Both types of enclosures had to be mountable in a 19 inch rack.

4.9.1 Node Enclosure

The node enclosures had to accommodate the STD card cage, the power supply and the optical assembly board. In addition, this enclosure had to provide a splash proof environment for its contents while still being able to provide adequate dissipation of the heat generated within the node.

Hammond was chosen as the supplier of the node enclosures because of their wide selection of enclosures, their versatility of enclosure design and their availability.

4.9.2 Splice/Star Coupler Enclosure

A survey indicated that there were very few suppliers of fusion splice enclosures that were suitable for mounting in a 19 inch rack. ITT Valtec was the only manufacturer able to supply an enclosure that could accommodate both the splices and the star couplers. These enclosures did, however, require some modifications.

Other splice enclosure suppliers whose products were considered include AMP and Siecor.

5.0 TESTING RATIONALE

The testing rationale was to conduct a comprehensive series of tests designed to prove the ability of each system element to meet its specifications and then to highlight system performance in order to generate data on which to base the draft standards. The testing was broken down into the following major phases:

- Component Acceptance Tests
- Major Assembly or Subsystem Tests
- Environmental Tests
- System Bench Tests
- Installation Tests
- Alongside Tests
- At Sea Tests
- Post Sea Tests

The collection of fibre and optical component performance data to support the development of standards came primarily from the alongside and at sea testing. The following subsections describe the basic testing philosophy.

5.1 Key Test Areas

The optical system performance was characterized during the alongside and at sea testing phases in the following key areas according to the noted criteria:

- Digital Data Transmission in terms of bit error rate (BER)
- Video Transmission in terms of picture quality
- Data Highway Operation in terms of throughput, response time, and IEEE-488 internest communication.

Data recorded in each of these areas was evaluated against the variables and controls for each test to determine, or to deduce along with other test results, the effect of shipboard operation on the optical assemblies.

5.2 Variables

Variations in the following system variables were tested during the shipboard testing:

- Optical Power (or Flux)
- Cable Type
- Cable Route

5.2.1 Flux

The system flux was varied through calibrated optical attenuators located at each of the remote nodes, i.e. the LBR and bridge nodes, between the node assembly and the transmissive star coupler.

The flux margin was measured as part of the system bench tests. This permitted accurate performance analysis at the design limit (in terms of flux and BER).

5.2.2 Cable Type

Two types of cable were installed in parallel to determine the performance and need for special cable protection under marine conditions.

One of the cables had both external armour and a vapour barrier for maximum environmental and mechanical protection, henceforth referred to as heavy duty (HD). The other cable was protected by its outer jacket only and referred to as light duty (LD).

5.2.3 Cable Route

As previously noted, the two cable types were installed in parallel over the same two routes. Refer to Figure 5.1. One route linked the bridge node to the transmissive star coupler located adjacent to the node in the machinery control room. This route provided environmental exposure by appearing on deck for a portion of the run. A second route linked the node in the lower boiler room to the transmissive star coupler and provided exposure to EMI especially in traversing the turbogenerator room; it also exposed the cables to high temperature and humidity.

The video camera on the winch control house top was linked via fibre optic cable to the node in the machinery control room, providing a further test of fibre cable performance under extreme environmental conditions. The HD cable was chosen for this route.

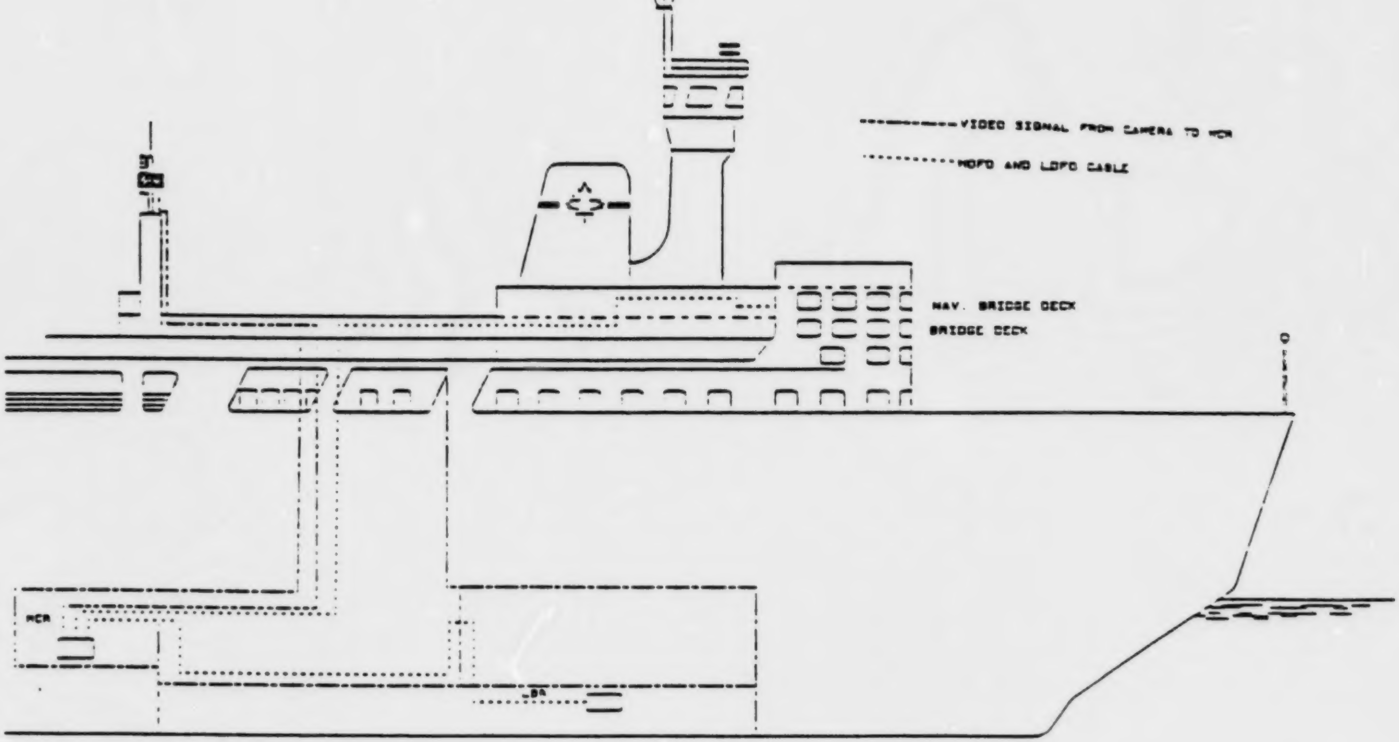

VIDEO SIGNAL FROM CAMERA TO MCR
HDFO AND LDFO CABLE
NAV. BRIDGE DECK
BRIDGE DECK
MCR
BR

Figure 5.1 Cable Routing

5.2.4 Components

Also included in the test plan were tests to evaluate the performance of the following optical components:

- Wavelength Division Multiplexers/Demultiplexers (WDM)
- Mechanical and Fusion Splices
- Sources

The WDM was examined for crosstalk in terms of the effect of the video signal (820 nm) on the digital BER performance (1300 nm).

In order to determine the performance of both mechanical and fusion splices, both types were used in the Data Highway node construction; however only one type was used in any particular node. The performance of each splice type was determined by changing the active route.

The long term degradation of the optical sources was monitored through power measurements.

In some cases, such as the star couplers, degradation during the tests was not expected. However the measurements made during the alongside tests (see 5.4) were designed to characterize the optical performance of each link, hence allowing data on which to isolate certain problems that may have occurred in components such as couplers.

5.3 Environmental Tests

The environmental testing included vibration and temperature testing of the major optical components and electronic assemblies. The vibration test was conducted according to MIL-STD-810D, Condition I, Method 5143 with a frequency sweep from 5 to 200 Hertz in all 3 principal directions of vibration. The vibration tests were non operating tests.

There were two phases of temperature tests, operating and nonoperating. The nonoperating tests covered the temperature range from 0 degrees C to -40 degrees C. The operating tests were conducted from 0 degrees C to +55 degrees C. In both cases the rate of temperature change was not less than 5 degrees C per minute. The units were permitted to stabilize at 0 degrees C and at both temperature extremes for 2 hours. The temperature tests on the components for the video link from the winch control house top to the machinery control room node had a soak time of 1 hour at the extremes and 0 degrees C as opposed to 2 hours.

5.4 Alongside Tests

The alongside tests included:

- source power measurements
- insertion loss measurements for each link and each cable
- optical crosstalk for the installed system
- optical isolation for the installed system
- eye pattern tests for the digital links
- optical time domain reflectometer (OTDR) tests

The purposes of these tests were to characterize the system components, cables and links, to verify the correct operation and for comparison purposes with later test results. Because of a delay in the vessel's sailing schedule, the at sea testing procedure started while the ship was alongside.

5.4.1 Eye Pattern Test

In addition to the alongside tests which are reported on in section 6.3, "Installation/Checkout Testing," eye pattern test were conducted on all of the digital links.

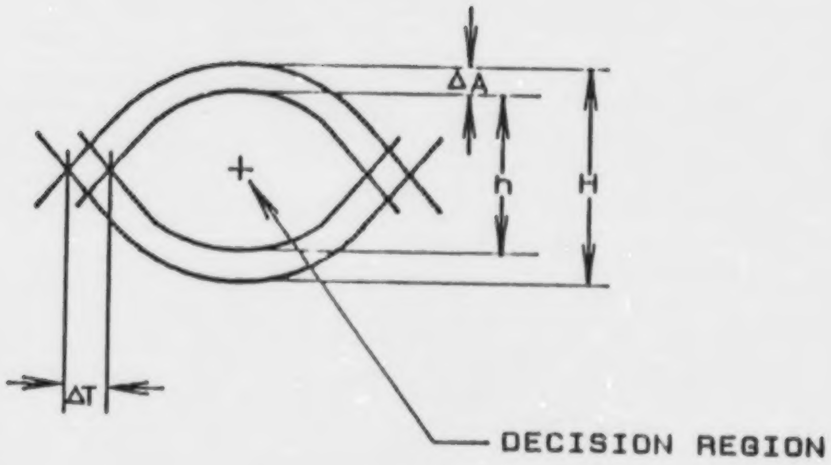
The eye pattern is generated by triggering an oscilloscope with the received clock and viewing the received data. The resulting display compares the uniformity of pulse widths and amplitudes by superimposing high to low and low to high transitions in a simple trace. The data source for the testing was a pseudo-random number generator.

The eye pattern is used to determine jitter and the signal to noise ratio of the line. Figure 5.2 "Eye Diagram" shows how these parameters are determined.

5.5 At Sea Tests

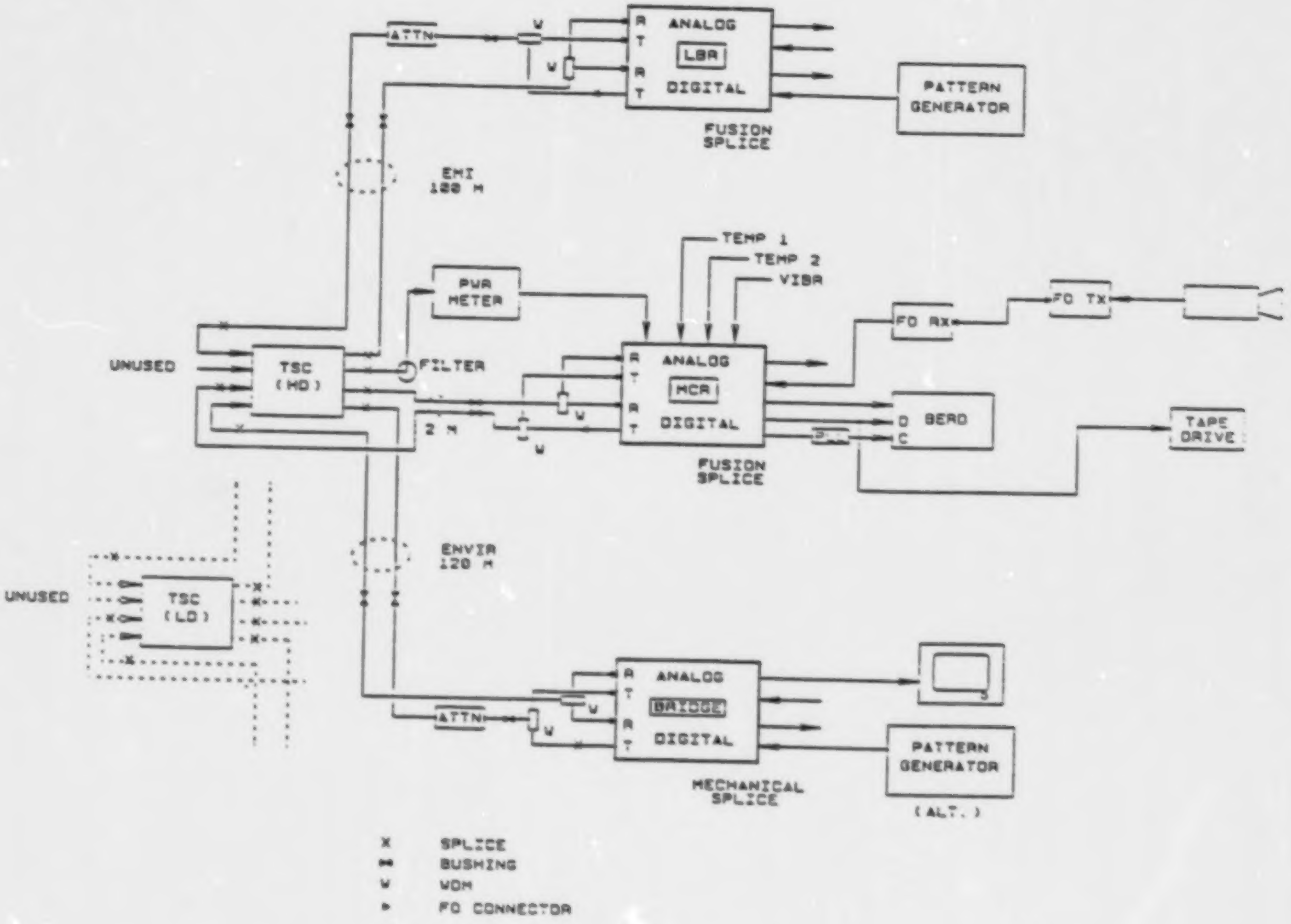
5.5.1 Bit Error Rate

The most objective measures of system performance were the bit error rate (BER), for digital data transmission between nodes, and the optical power. The BER was monitored between two nodes under varied flux, component, cable type, cable routing and vessel operating conditions. The basic configuration for this test is shown in figure 5.3 "System At Sea Test Configuration." The optical power was monitored at the unused leg of the star coupler, as shown in the figure.


ΔA
h
H
ΔT
DECISION REGION

ΔT = jitter
S/N = 20 log H/h dB

Figure 5.2 Eye Diagram



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LBR
DIGITAL
PATTERN GENERATOR
FUSION SPLICE
EMI 120 M
TEMP 1
TEMP 2
VIBR
PWR METER
FO RX
FO TX
UNUSED
TSC (HD)
FILTER
ANALOG
MCR
DIGITAL
R
T
R
T
W
W
2 M
D
C
BERD
TAPE DRIVE
FUSION SPLICE
ENVIR 120 M
UNUSED
TSC (LD)
ANALOG
BRIDGE
DIGITAL
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ATTN
W
W
PATTERN GENERATOR
(ALT.)
MECHANICAL SPLICE
X SPLICE
BUSHING
W VOM
FO CONNECTOR

Figure 5.3 System at Sea Test Configuration

5.5.2 Route and Cable

The data route was varied by moving the pseudorandom number generator (PRNG) to either the lower boiler room (LBR) node or to the bridge node. Along each of these routes, the cable was selected by changing over to either the HD or the LD cable at the transmitting node, the receiving node and at the star coupler connection to the optical power meter. The physical change was by way of SMA connectors at a bushing bracket in each node. By recording operational data along the two routes and both cables, the effects of EMI and temperature extremes could be analyzed for both cable types.

5.5.3 Flux

Flux was controlled with an optical attenuator, one of which was located in each of the remote nodes. By reducing the flux level to the minimum required for system operation, simulating long term degradation, the system was made as sensitive as possible to the shipboard environmental conditions.

5.5.4 Digital System Evaluation

The performance of the two cables, along both routes and at the various flux levels was determined by analyzing the BER. The BER, sensor data and date/time group were recorded by a tape drive under the control of the data logger. A detail description of the data format is given in section 6.5.2.

5.5.5 Analog System Evaluation

Analysis of the video system performance was purely subjective. A log book was provided for the officer on watch to record the quality of the picture. The video system was considered as secondary to the digital system from the standpoint of analyzing system performance.

5.6 Post Sea Trials

The post sea testing began with a visual inspection of the system and system components for signs of deterioration. Some of the original alongside tests were then repeated so that the optical chracteristics of the cable, sources and optical components could be compared with their performance before the sea trial period. Also included in the post sea trial tests were a repeat of some of the at-sea tests, in areas where additional data was desired to search for correlations (eg. whether the LD cable losses would vary with thermal cycles through the freezing point).

6.0 TESTS AND RESULTS

6.1 Tests Performed

There were several phases involved in the project, most of which involved some testing. This testing was broken down in the foregoing section.

6.2 Bench Testing

The bench testing was divided into two parts: the acceptance testing and the environmental testing.

6.2.1 Acceptance Tests

The acceptance tests were performed to check the manufacturer's specifications against the design specification, as laid down on the applicable Specification Control Drawing.

6.2.1.1 Cable Acceptance

A summary of the light duty and heavy duty cable acceptance test results is given in table 6.2.1, "Cable Acceptance." Both cables met or exceeded the design specifications in terms of optical characteristics, configuration, mechanical properties and materials. Details on these results are given in Appendix A.

6.2.1.2 Star Coupler Acceptance

A summary of the star coupler acceptance test results is given in tables 6.2.2 and 6.2.3. In general, both couplers were within the design specifications. The notable variation was in the insertion loss which varied from the specified maximum of +/-1 dB to approximately +/- 1.5 dB. This variation was not seen as a problem because input/output ports with higher insertion loss could be matched with cable runs having lower insertion loss so that the flux distribution over the system could be equalized.

Details on the test results, the manufacturer's specifications and design specifications are given in Appendix A.

Table 6.2.1 Cable Acceptance

	SPECIFICATION		SUPPLIER		ACCEPTANCE	
	HD	LD	HD	LD	HD	LD
LENGTH (m)	300	-0,+10%	300	300	307	301
ATTENUATION (dB/km)	FIBRE < 5 (850 nm) & 1 dB FOR CABLE		6.0	7.0	6.5 (ON SPOOL)	4.2
BEND RADIUS (mm)	<= 150	<=120	123	75	123	75
CONSTRUCTION	DRWG. 3-8468-201-0 DRWG. 3-8468-202-0				MET/EXCEEDED	
TERMINAL TUBE (COMPRESSION)					NO LOSS INCREASE	

Table 6.2.2

Transmissive Star Coupler Acceptance Test Results

Ref. Dwg. No. 3-8468-291-0
Make: Canstar
Model #PCS 4X4-100
Serial #184-1050P
Wavelength - 820 nm

		Input			
	Port	1	2	3	4
	A	7.06	6.92	5.26	6.96
Output	B	6.96	7.06	6.83	4.98
	C	5.19	6.91	6.69	5.71
	D	6.98	5.33	7.03	7.08

Insertion Loss dB

Specification: 8 dB per port +/- 1 dB

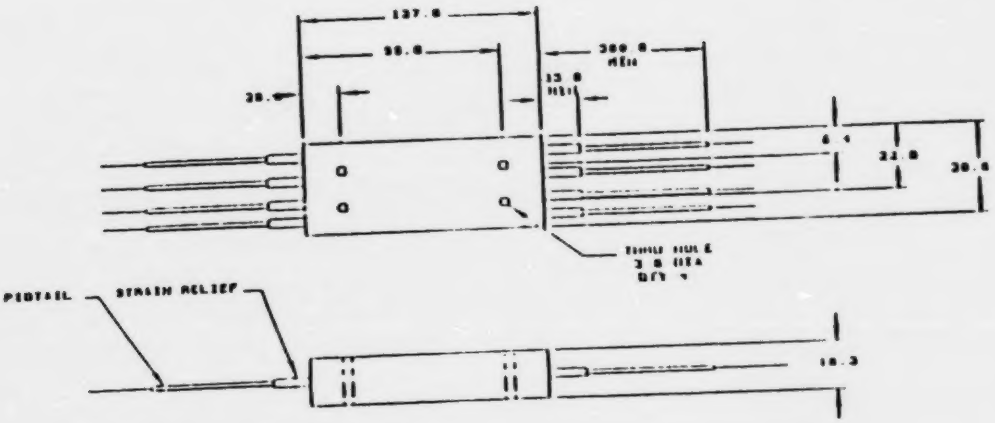

127.0
95.0
300.0 MIN
20.
15.0 MIN
6.4
22.0
30.0
THRU HOLE 3.0 DIA QTY 4
PIGTAIL
STRAIN RELIEF
18.3

Table 6.2.3

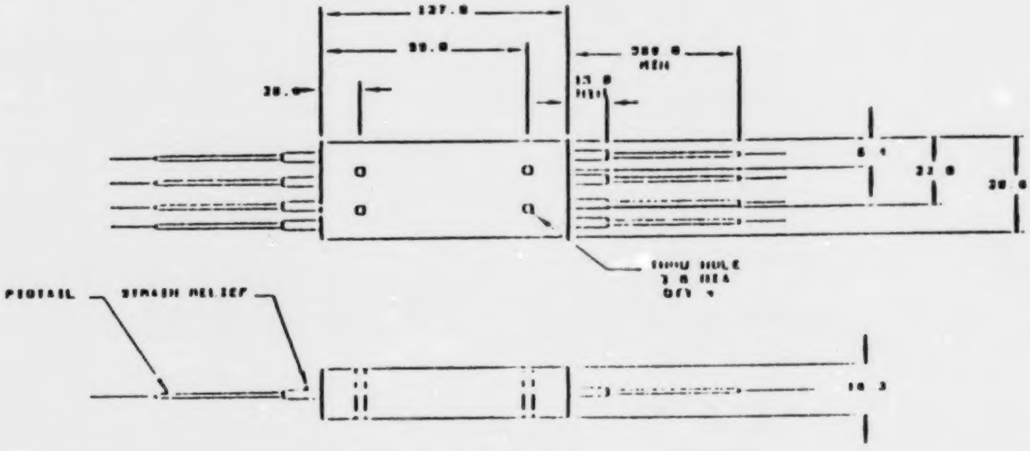
Transmissive Star Coupler Acceptance Test Results No. 2

Ref. Dwg. No. 3-8468-291-0
Make: Canstar
Model #PCS 4X4-100
Serial #84-1274P
Wavelength - 820 nm

		Input			
	Port	1	2	3	4
Output	A	7.34	5.82	8.06	7.68
	B	5.79	7.28	8.33	7.22
	C	7.75	7.62	5.10	8.02
	D	7.29	7.73	8.33	5.48

Insertion Loss dB

Specification: 8 dB per port +/- 1 dB


127.0
MIN
MIN
THRU HOLE
QTY 4
PIGTAIL
STRAIN RELIEF

6.2.1.3 Wavelength Division Multiplexer Acceptance

There were a total of six wavelength division multiplexers/demultiplexers included in the system design. The average of the test results for all six is given in table 6.2.4, "Wavelength Division Multiplexer (WDM)." All of these devices either met or exceeded the design specifications in terms of insertion loss, isolation, and crosstalk.

Details on the test results, as well as the manufacturer's specifications and design specifications are given in Appendix A. The optical assemblies, at the time of testing, consisted of the wavelength division multiplexers mounted on the assembly boards.

6.2.1.4 Transmitters/Receivers Acceptance

There were three transmitters at each operational wavelength and three receivers at each of the operating wavelengths as well as a separate transmitter and receiver for the video link from the camera to the machinery control room node. Typical test results for these devices are given in table 6.2.5 "Transmitters/Receivers."

A system design change, replacing the reflective star couplers with transmissive star couplers, enabled the relaxing of some of the transmitter and receiver specifications so that the devices were acceptable within the revised system design specifications.

A typical example of the frequency response of one of the video cards is shown in Figure 6.2.1 "Frequency Response, Video Board S/N 101."

Acceptance testing was also conducted on the optical transmitter and receiver used to form the video link from the camera to the MCR node. This link was found to be acceptable. A detailed report on the test results can be found in Appendix A, "Test Results."

Table 6.2.4 Wavelength Division Multiplexer (WDM)

	SPECIFICATION	SUPPLIER (JDS Optics) WD813	ACCEPTANCE (TYPICAL, AVG. OF 6)
INSERTION LOSS (dB)	< 1.5	<= 2.0	1.3
ISOLATION (dB)	> 20	N/S	> 90 (820nm) > 50 (1300nm)
CROSSTALK (dB)	< 25	< 20 (820nm) < 28 (1300nm)	< 90 (820nm) 28.8 (1300nm)

Table 6.2.5 Transmitters/Receivers

---------- VIDEO 820 nm ----------

	SPECIFICATION	SUPPLIER	ACCEPTANCE
FLUX BUDGET (dB)	> 30	30	> 32
BANDWIDTH (-3 dB, MHz)	> 10	10	4
SNR (dB)	> 42	42	N/A

---------- DIGITAL 1300 nm ----------

	SPECIFICATION	SUPPLIER	ACCEPTANCE
FLUX BUDGET (BER 10E-9, dB)	> 28	16	23
DATA RATE (Mbps)	> 1	2	2

---------- VIDEO 820 nm (Link from mast) ----------

	SPECIFICATION	SUPPLIER	ACCEPTANCE
FLUX BUDGET (dB)	> 30	30	> 32
BANDWIDTH (-3 dB, MHz)	> 10	10	4
SNR (dB)	> 42	42	N/A

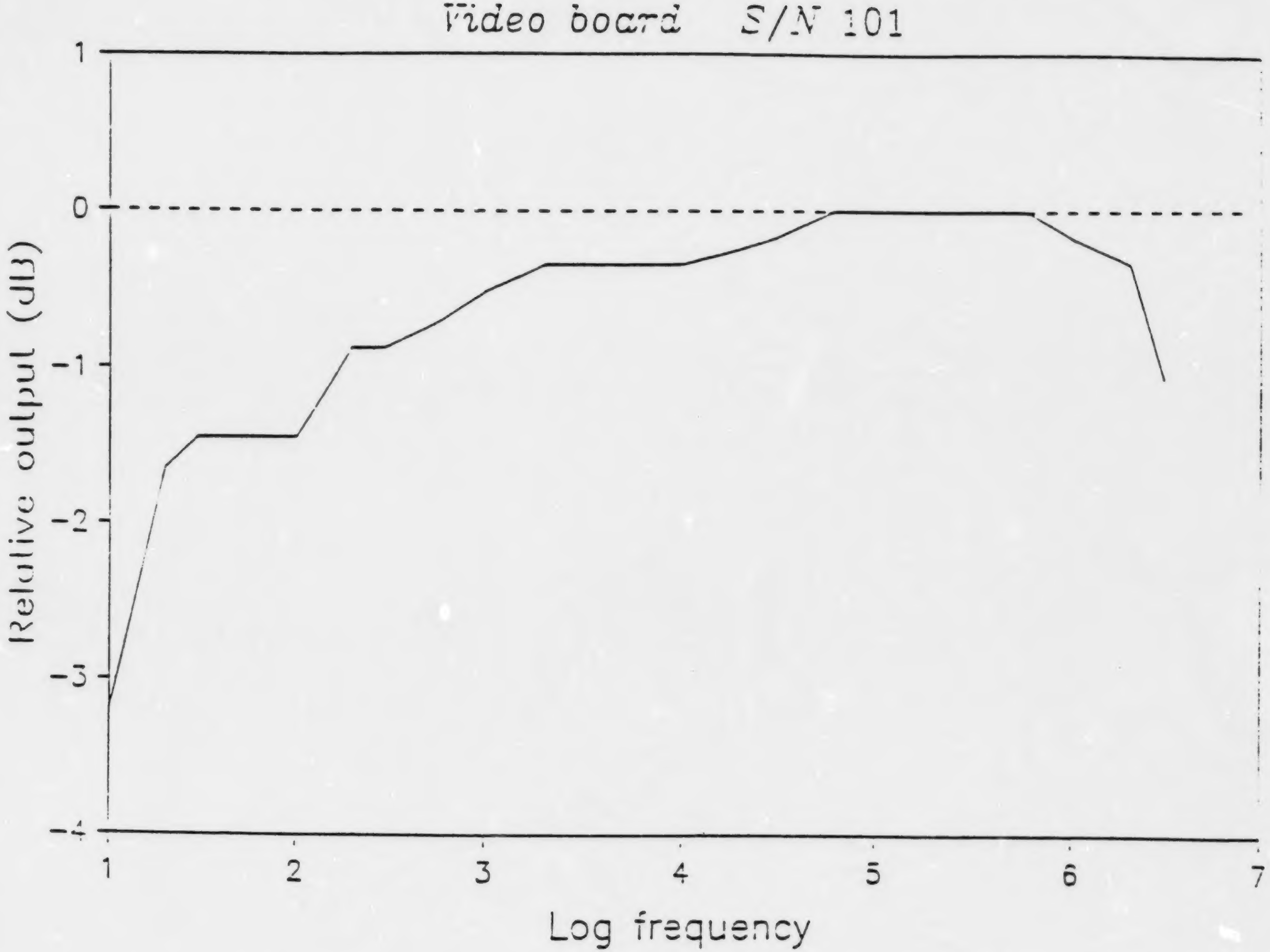


Figure 6.2.1 Frequency Response

6.2.1.5 Electronic Data Highway Acceptance

The purposes of the scientific data highway (SDH) acceptance tests were to determine the increase in response time as well as the decrease in throughput caused by the SDH. Test results revealed that, on the average, total transaction time was increased by 70% because of the SDH. The throughput of the SDH was also demonstrated satisfactorily by the supplier. A detailed report on these test results can be found in Appendix A, "Test Results."

6.2.2 Environmental Tests

The environmental tests were conducted to verify that the system components would not be adversely affected within the limitations of the normally expected operating and/or storage environment.

6.2.2.1 Vibration

Two nodes and one star coupler were tested in accordance with MIL STD 167B, 'Mechanical Vibrations of Shipboard Equipment'. When the first node was tested, some of the power supply components, mostly capacitors, broke free. Power supply components in all three nodes were provided with extra support which proved effective when the second node was tested.

The vibration test revealed the requirement for some additional stiffening for both the node enclosure and the star coupler enclosure to prevent mechanical oscillation. It was also necessary to "tack down" some of the wires. Further testing verified the effectiveness of these modifications.

There was no change in the coupling losses as measured before and after the vibration testing. A brief summary of these test results is given in table 6.2.6 'Environmental Testing - Vibration' and a detailed report is given in Appendix B, "Environmental Test Results."

6.2.2.2 Temperature

All three nodes and both star couplers were temperature tested from -40 degrees Celsius to +55 degrees Celsius for storage and 0 degrees Celsius to +55 degrees Celsius for operation. A summary of these test results is shown in table 6.2.7 "Environmental Testing-Temperatures."

During the operational temperature testing, the data highway was running a "sanity checking" program. The video system was operational, using a video camera and a monitor to ascertain the performance level. Also, an oscilloscope was used to help characterize the video output of the receiver.

At the time of the temperature testing, the digital channel was not operational due to the failure of the digital transmitters and receivers to pass the acceptance tests.

The first round of temperature testing revealed that the temperature compensating portion of the video receiver circuit was responding in the reverse of the expected manner. This resulted in the modification of the compensating circuit on all three video cards and subsequent retesting.

One of the CPU cards exhibited an intermittent failure to initialize the digital card at low temperatures. A defective logic gate and capacitor were subsequently replaced on this card.

The test configuration for the temperature testing is shown in Figure 6.2.2, "Temperature Test Configuration." A detailed report on these test results is given in Appendix B, "Environmental Test Results."

Table 6.2.6 Environmental Testing - Vibration

- TWO NODES (MECHANICAL AND FUSION SPLICE) AND ONE STAR COUPLER WERE VIBRATED ACCORDING TO MIL STD 167
- POWER SUPPLY CAPACITORS BROKE FREE
- SOME CHASSIS STIFFENING ADDED
- NO CHANGE IN COUPLER LOSS DURING / AFTER TESTING
- POST CRUISE VISUAL INSPECTION REVEALED NO MAJOR DAMAGE

Table 6.2.7 Environmental Testing - Temperature

- THREE NODES AND STAR COUPLER CYCLED. -40°C TO 55°C, 0 TO 55°C OPERATING
- TWO NODES PASSED; CAPACITOR AND BAD GATE ON CPU BOARD REPLACED ON THIRD
- VIDEO RECEIVERS REQUIRED CHANGE TO TEMPERATURE COMPENSATION CIRCUIT (APD)
- DIGITAL TRANSMITTERS SHOWED USUAL LED TEMPERATURE DEPENDANCE; RECEIVERS SUFFERED FROM OSCILLATION

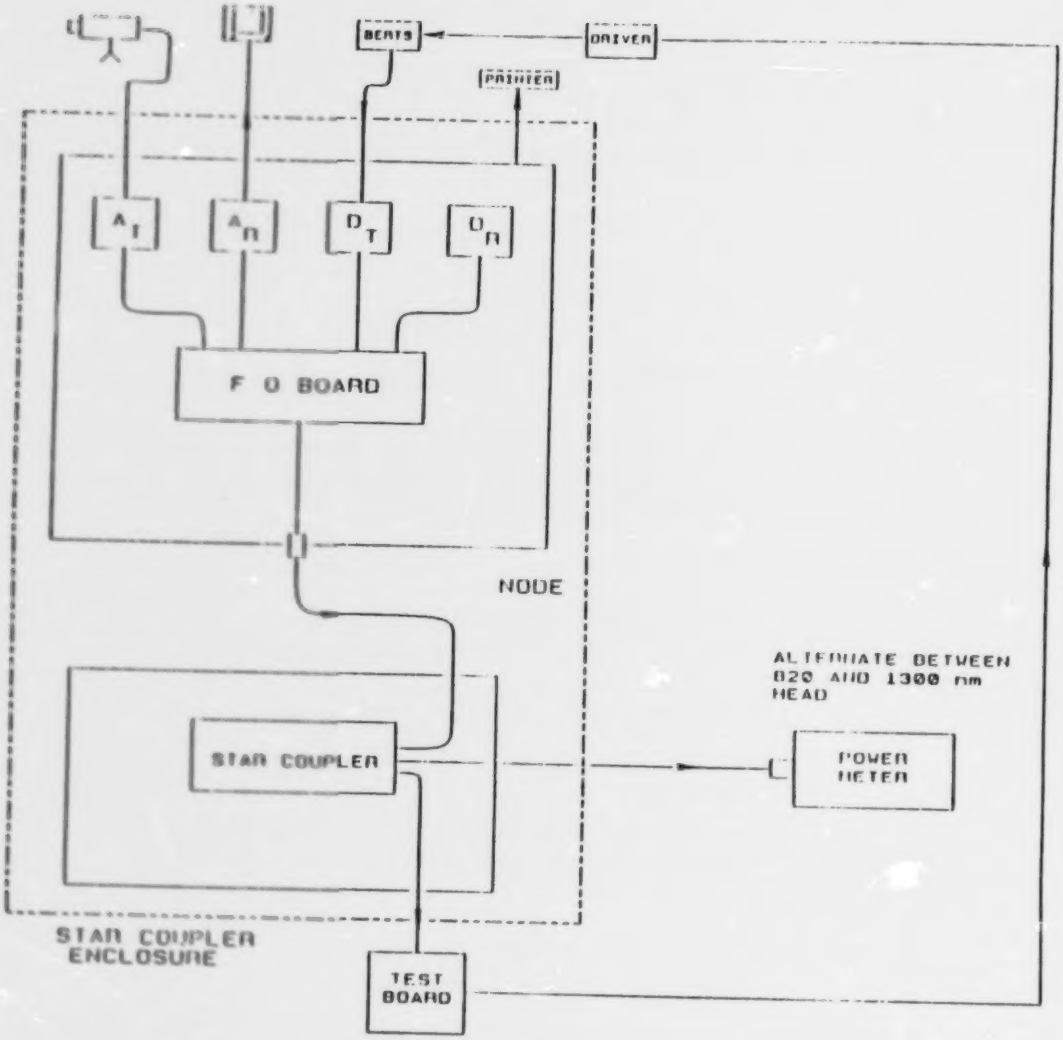

BERTS
DRIVER
PRINTER
A_T
A_R
D_T
D_R
F O BOARD
NODE
ALTERNATE BETWEEN
820 AND 1300 nm
HEAD
STAR COUPLER
POWER
METER
STAR COUPLER
ENCLOSURE
TEST
BOARD

Figure 6.2.2 Temperature Test Configuration

Following the sea trial test period, the temperature test was repeated with the as-fitted digital cards. This testing was done because of an observed response of the digital receivers to elevated temperatures during post sea trial bench testing of the digital cards and anomalies seen when analyzing the logged data.

The digital transmitter was cycled from 0 degrees Celsius to +55 degrees Celsius three times over a two hour period. During that time, the output power was observed to vary, over a 2 dB range, inversely to the temperature. The plots of these results are shown in Figure 6.2.3, 'Output Power vs. Temperature.'

A second temperature cycle test was conducted to characterize the response of the digital receivers. The results of the test are displayed in figure 6.2.4, 'Receiver Oscillation vs. Temperature.' Between 41 degrees Celsius and 43 degrees Celsius, the receivers would start to oscillate and continue to do so until the temperature dropped below the 41 to 43 degrees Celsius level.

6.3 Installation/Checkout Testing

At various times during the installation process, different aspects of the system were checked to verify that they were installed properly and to characterize the system. Included in this testing was some trouble-shooting to correct problems.

The installation testing included:

- OTDR traces on all of the installed fibres
- insertion loss measurements on all of the links at both wavelengths
- system crosstalk measurements.

6.3.1 OTDR Test

The OTDR traces were recorded as photographs and intended to be used for before and after comparison of the fibres. Figure 6.3.1 'Optical Time Domain Reflectometry' shows the operating theory of the OTDR. The OTDR is often used as a fault locator.

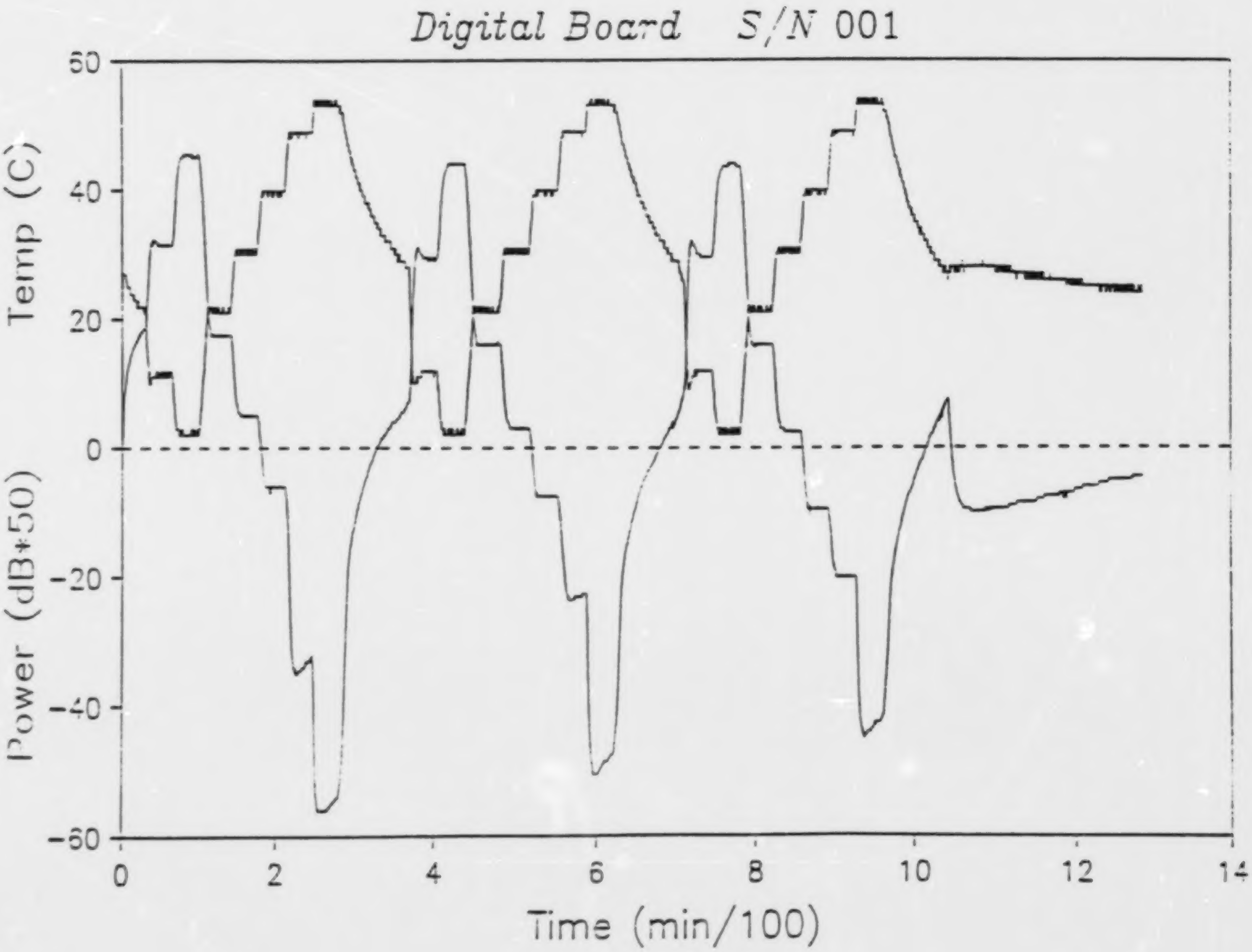


Figure 6.2.3 Output Power vs Temperature

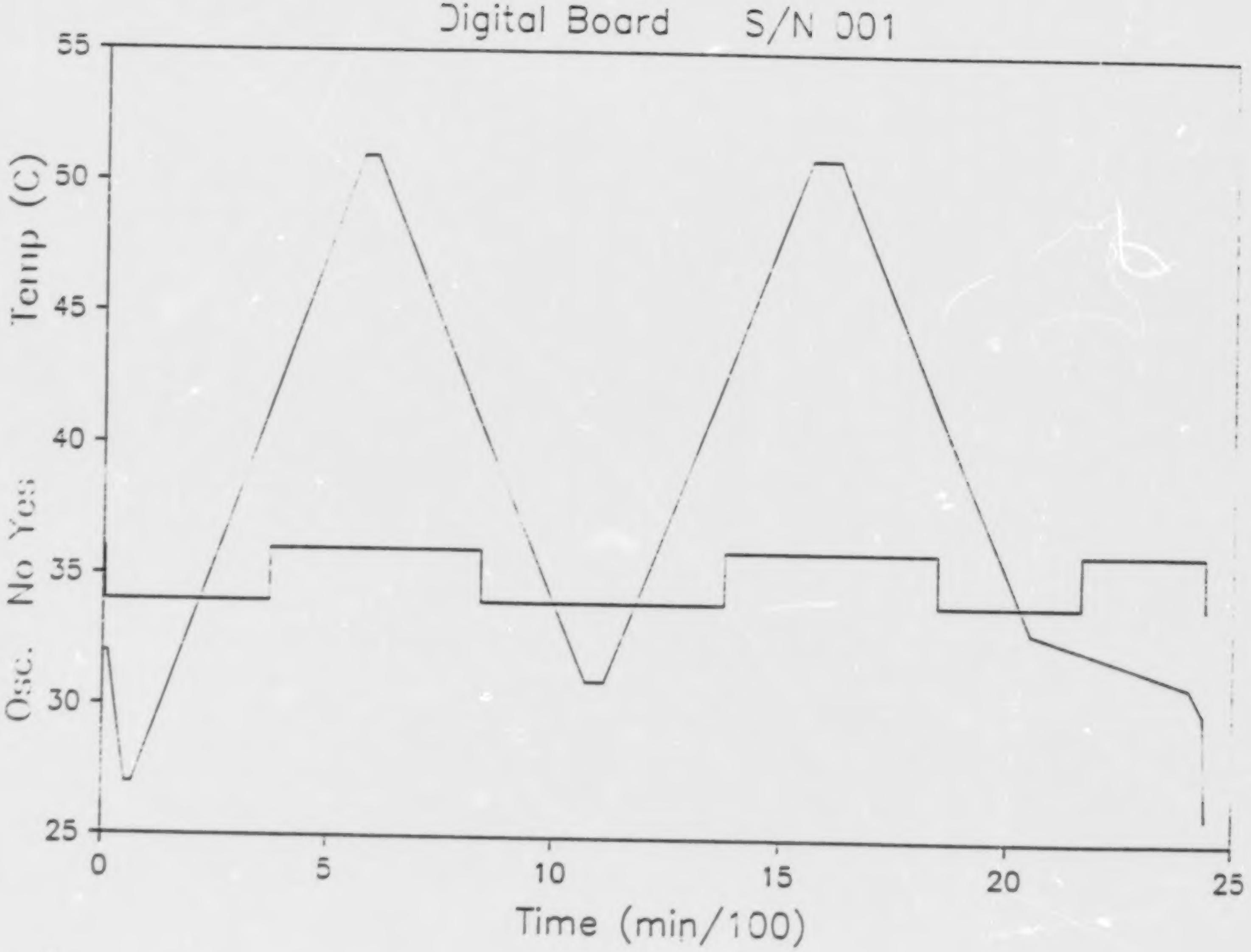


Figure 6.2.4 Receiver Oscillation vs Temperature

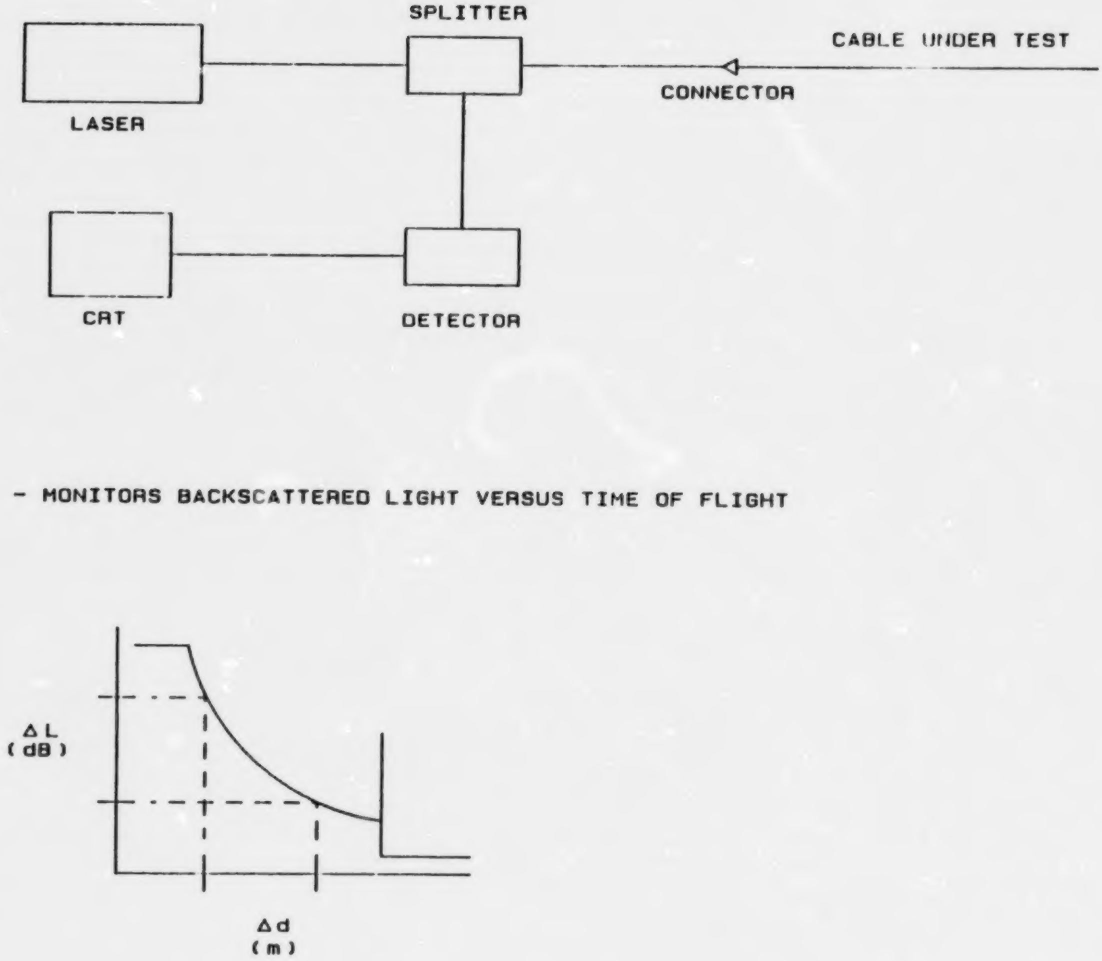

SPLITTER
CABLE UNDER TEST
CONNECTOR
LASER
CRT
DETECTOR
- MONITORS BACKSCATTERED LIGHT VERSUS TIME OF FLIGHT
ΔL
(dB)
Δd
(m)

Figure 6.3.1 Optical Time Domain Reflectometer (OTDR)

A sample of the results of before and after OTDR comparison is included in table 6.3.1, 'Cable Loss Performance (OTDR)."

An interesting point to note in these results is that, for the fibre along the EMI route, in the light duty (LD) cable, the specific loss decreased from 3.0 dB to 2.2 dB over the period from December 15, 1985 to February 15, 1987. Only a part of this 0.8 dB increase in power can be attributed to operator error. Although not anticipated, it was explainable according to speakers at the 1987 Marine Technology Society workshop on Marine Cables and Connectors, which was held in Houston, Texas. In some cases, the fibre in an installed cable will relax, reducing the installed strain and with it some of the microbending forces. The net result is a decrease in the measured loss of the installed fibre.

6.3.2 Insertion Loss Test

Insertion loss measurements were made at both wavelengths along the installed links. For the purpose of these tests, the optical sources were the sources as fitted in each node. The output power from the analog transmitters was the quiescent power level while the digital transmitters were modulated with a 1 Mbit TTL, 50% duty cycle signal. The results of the before and after insertion loss measurements are given in Appendix C "Installation Test Results."

6.3.3 Crosstalk Test

Crosstalk measurements were made for both operating wavelengths along each of the links. In all cases, the crosstalk was better than the design specification limits. A detailed report on the results of the crosstalk measurements is given in Appendix C, "Installation Test Results."

6.4 Alongside Test

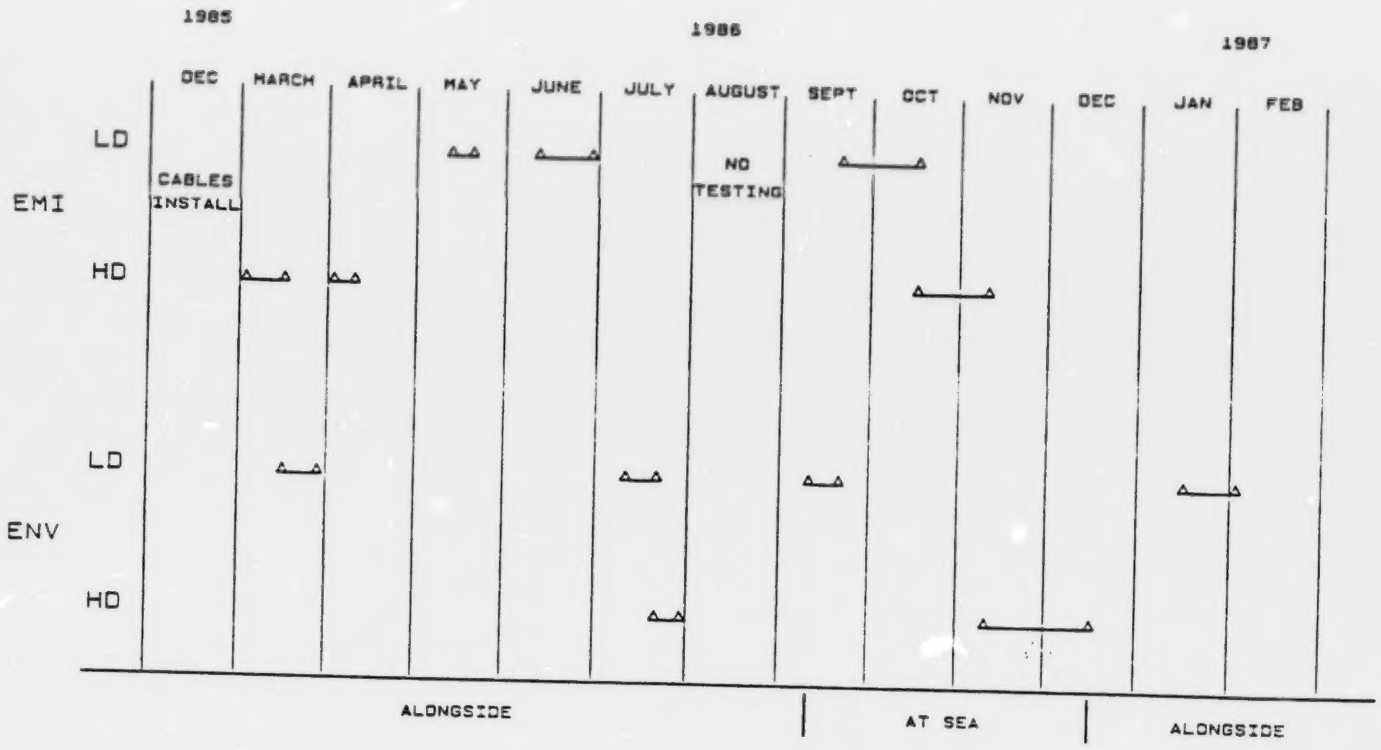
6.4.1 Test Schedule

The normal sailing schedule of the test vessel was interrupted by a motor room fire in late December, 1985. Table 6.4.1 'Test Schedule,' shows the schedule for alongside and at sea testing. During the extra time alongside for repairs, the tests conducted were similar to the

Table 6.3.1 Cable Loss Performance (OTDR)

ROUTE	CABLE	LENGTH (m)	LOSS 15 DEC 85 (dB)	LOSS 15 FEB 87 (dB)
EMI	LD	59.0	3.0	2.2
EMI	HD	58.5	1.5	1.6
EMV	LD	128.0	2.5	2.5
EMV	HD	124.0	2.4	2.5

Table 6.4.1 Test Schedule



at sea tests except that the environmental conditions did not reflect the normal operating conditions. Also, during that time, the bit error rate test set (BERTS) was removed from the vessel on several occasions, interrupting the data logging procedure.

The data obtained during this test period was combined, for analysis, with the data from the sea trial test period.

6.4.2 Test Configuration

During the alongside and at sea testing periods, the system was configured as shown in figure 6.4.1, 'System Configuration.' The MCR node acted as the digital receiver node as well as the data logger controller.

Digital data was provided by a pseudo-random number generator (PRNG) which generated a 2 -1 pattern at 500 Kbps. This generator was alternately located at the bridge node and the lower boiler room (LBR) node so that both the environmental (ENV) and the electromagnetic interference (EMI) routes could be exercised. Data was transmitted from each of these remote nodes via an optical attenuator so that the flux level could be controlled.

The MCR node received the digital data from the remote nodes and, after having converted it from an optical signal to an electrical signal, passed it on to the decoder where the clock and data were separated before going to the bit error rate test set (BERTS) for analysis. The BERTS determined the received clock frequency, the identity of the received pattern, the total number of error bits and the bit error rate (BER). Under the control of the data highway controller, this information was recorded by the tape drive.

The data logger also recorded data from four sensors. These included vibration, inboard and outboard temperatures and optical power. Except for the optical power, the sensor measurements were intended as nominal values used to characterize the general status of the vessel. For example the vibration would be higher during icebreaking, but the absolute reading was meaningless. The optical power was measured at the fourth output from each of the transmissive star couplers (TSC). In order to measure only

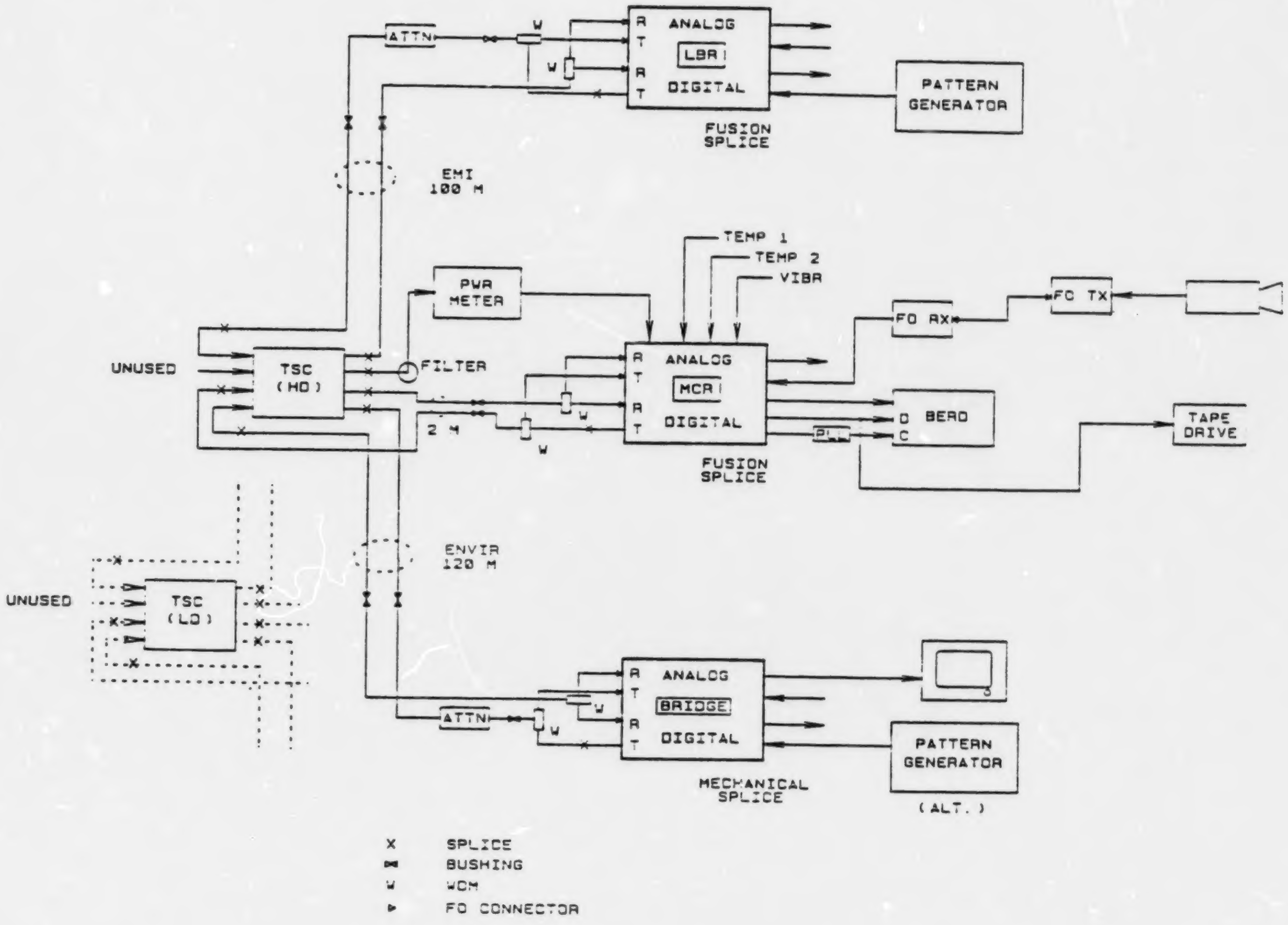

ATTN
W
W
R
T
R
T
ANALOG
LBR
DIGITAL
PATTERN GENERATOR
FUSION SPLICE
EMI 100 M
TEMP 1
TEMP 2
VIBR
PWR METER
FO TX
FO RX
UNUSED
TSC (HD)
FILTER
R
T
R
T
ANALOG
MCR
DIGITAL
W
W
2 M
D
C
BERD
PLL
TAPE DRIVE
FUSION SPLICE
ENVIR 120 M
UNUSED
TSC (LD)
R
T
R
T
ANALOG
BRIDGE
DIGITAL
ATTN
W
W
PATTERN GENERATOR
(ALT.)
MECHANICAL SPLICE
X SPLICE
BUSHING
W WDM
FO CONNECTOR

Figure 6.4.1 System Configuration

the optical power associated with the digital transmission and to disregard the effect of the short wavelength video transmission, a long pass dichroic interference type filter was installed at the detector head of the optical power meter.

The MCR node was the broadcast node for the video signal from the camera on the winch control house top. A separate optical link delivered the video signal to the MCR node from the camera. Although all three nodes received this video signal, only the bridge node was fitted with a video monitor. Similarly, the digital broadcast signal was received by all three nodes, but only the MCR node had access to the devices required to interpret and record this information.

The data logger provided a time and date stamp for the data records and formatted the BERTS and sensor data for recording by the tape drive. The data format is shown in figure 6.4.2, "Data Logger Recorded Format."

6.5 At Sea Tests

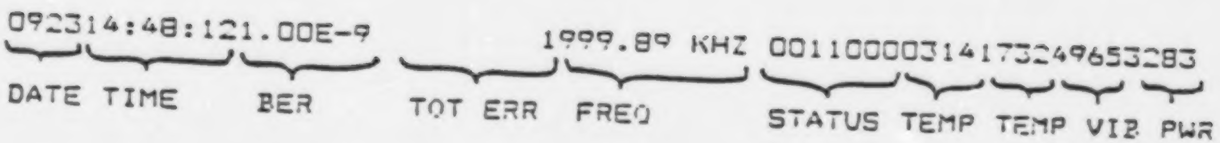
The at sea testing consisted mainly of bit error rate (BER) testing. Results from this testing, along with several environmental and operational parameters, were monitored and recorded.

Figure 6.5.1 'Bit Error Rate Test Configuration,' shows the essence of the BER test configuration and the Manchester encoding scheme used to encode the clock and data for serial transmission.

6.5.1 BER Limitations

In an optoelectric system such as a fibre optic communication link, there are quantum limitations to the system performance. Figure 6.5.2 "Error Probability" shows the plot of signal to noise ratio (SNR) necessary to maintain a given maximum error rate. Using this relationship, a signal to noise ratio (SNR) of 21.7 is required to achieve a bit error rate (BER) of 10^{-9}.

Table 6.5.1 "Detector Characteristics" gives a comparison of the characteristics of some common detector configurations. In the given example, if the receiver were a Si PIN device, it would not be within the limitations of the device to expect to obtain a BER of 10^{-9} when the received



```
092314:48:121.00E-9          1999.89 KHZ 00110000314173249653283
```

DATE
TIME
BER
TOT ERR
FREQ
STATUS
TEMP
TEMP
VIB
PWR

Figure 6.4.2 Data Logger Record Format

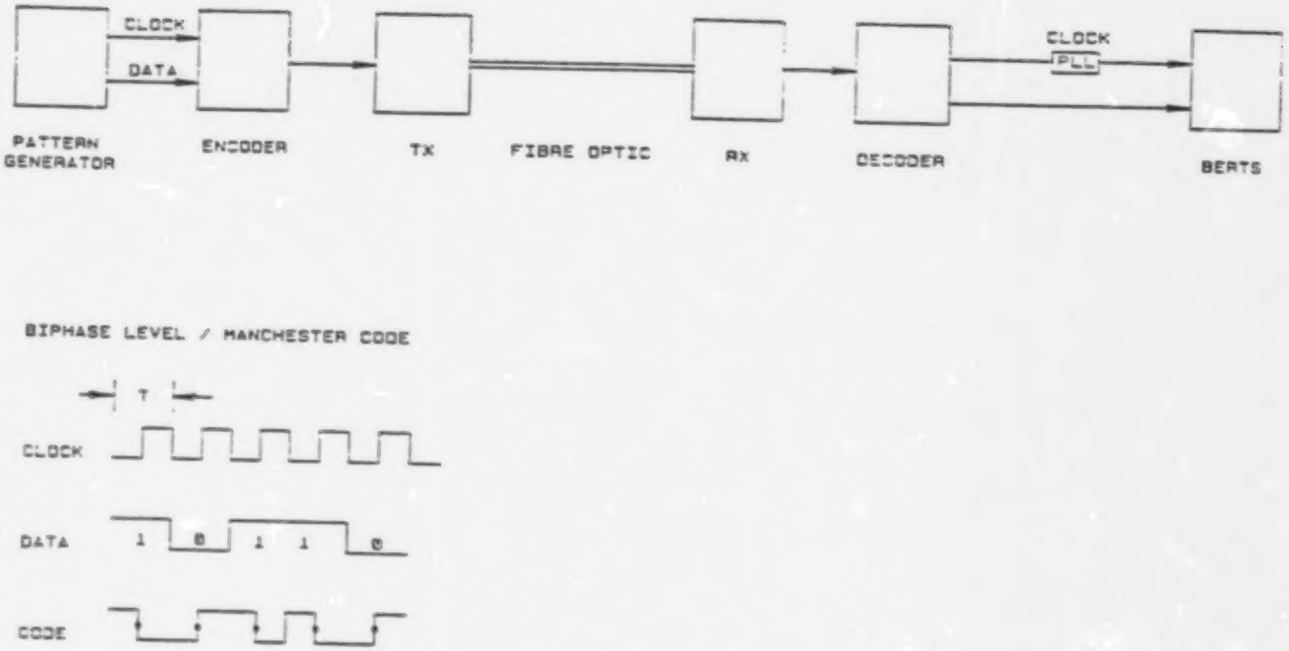
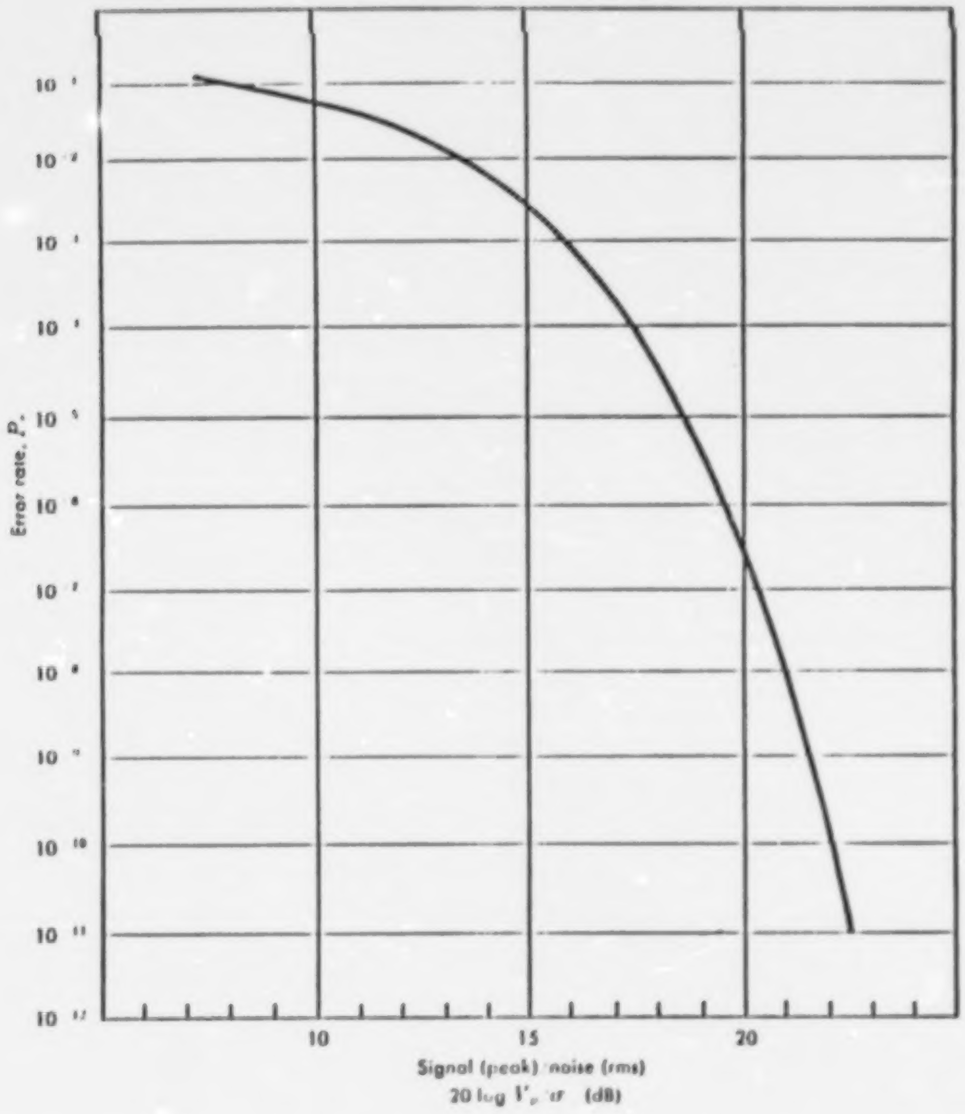

CLOCK
DATA
PATTERN GENERATOR
ENCODER
TX
FIBRE OPTIC
RX
DECODER
CLOCK
PLL
BERTS
BIPHASE LEVEL / MANCHESTER CODE
T
CLOCK
DATA
1 0 1 1 0
CODE

Figure 6.5.1 Bit Error Rate Test Configuration



$$p(\text{error}) = \frac{1}{\sqrt{2\pi}\,\sigma} \int_{\frac{1}{2}V_p}^{\infty} e^{-v^2/2\sigma^2}\, dv$$

Figure 6.5.2 Error Probability

Table 6.5.1 Detector Characteristics

Material	Structure	Rise Time (ns)	Wavelength (nm)	Responsitivity (A/W)	Dark Current na	Gain
Si	PIN	0.5	300-1100	0.5	1	1
Ge	PIN	0.1	500-1800	0.7	200	1
InGaAs	PIN	0.3	1000-1700	0.6	10	1
Si	APD	0.5	400-1000	77	15	150

Ex: Quantum limit for Si PIN for BER 10^{-9} (SNR 21.7)

$i_s = i_n * 10^{\frac{SNR}{20}}$

$= 12$ na

$= 24$ nW (optical power)

$= -46$ dBm

power is less than -46 dBm. The quantum limit demonstrated here is the ideal limit which may not be achieved in an installed system.

A typical plot of receiver sensitivity for the long wavelength Si avalanche photodiode (APD) used in this system is shown in figure 6.5.3 "Receiver Sensitivity". The plot shows the result of received power on the BER. At the limit of receiver sensitivity, a change of as little as 0.3 dB in received power results in several decades of change in BER.

Hence the optical power was seen to be a more convenient measure of system performance than was BER, as it gave a continuously varying response rather than a "yes/no" condition.

6.5.2 BER Testing Data Format

The BER files were logged in two formats, one for hourly records and the other for event records. Examples of each of these are given in figure 6.5.4, 'Hourly File' and figure 6.5.5 'Error Event File.'

In both cases the record format was the same, consisting of the date, time, error rate, total errors, received frequency, seven BERTS status indicators and four digitized environmental and operational sensor codes. These sensors include the optical power as measured at the fourth output of the star coupler, the vibration at the MCR node rack, the external temperature in close proximity to the optical cable along the environmental (ENV) route, and the temperature inside the MCR equipment rack.

The hourly files included the 'on hour' record as well as the records containing the minimum and maximum data from each of the four sensors for a total of nine records.

The error event files contain the records recorded at ten second intervals for five minutes before until five minutes after an error. In the situation of figure 6.5.5, the presence of 8676 errors in fact shows a loss of synchronization by the BERTS. Analysis of these records assists in determining which of the environmental and operational parameters being monitoring influenced the loss of synchronization.

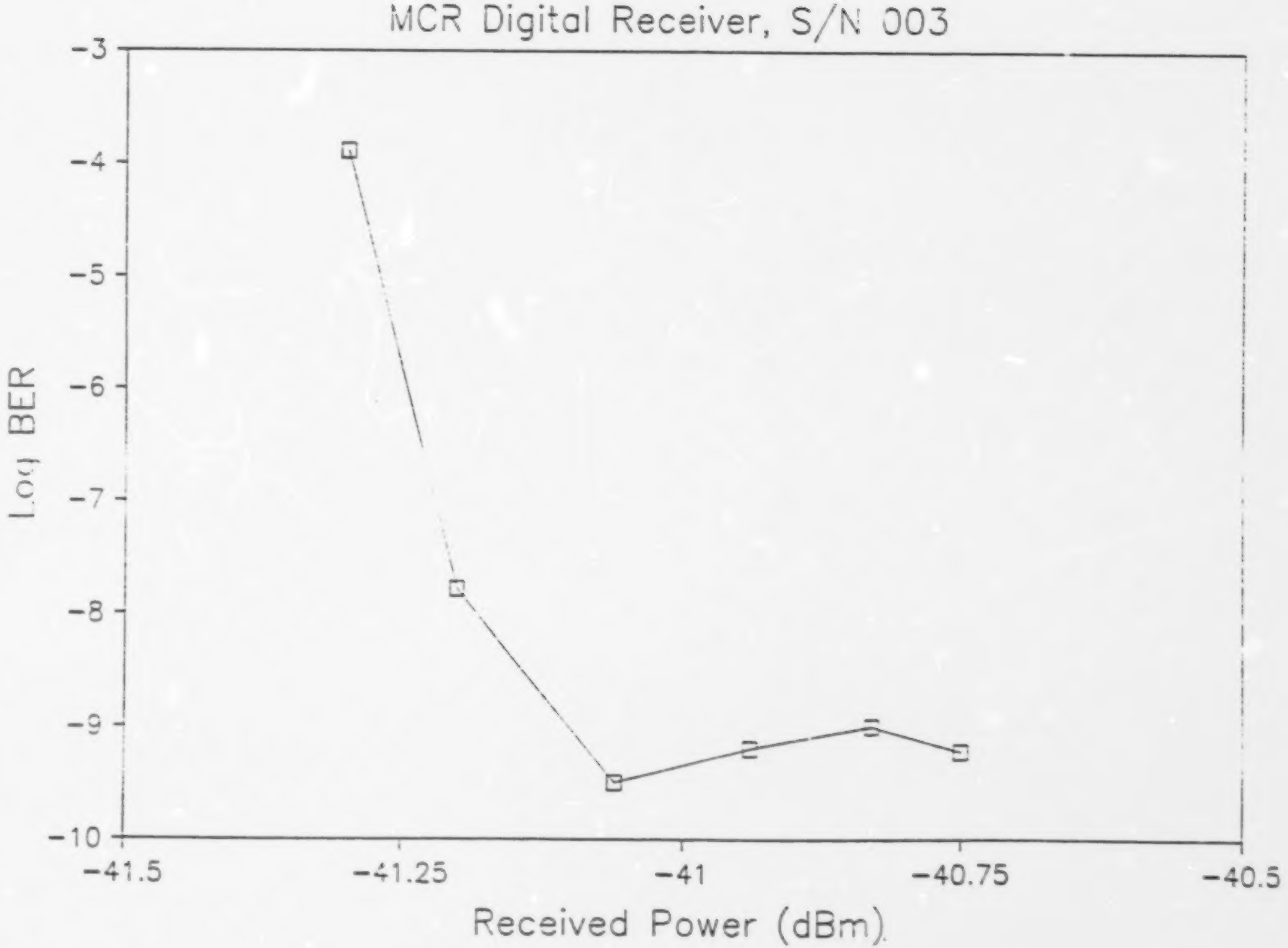


Figure 6.5.3 Receiver Sensitivity

```
102512:00:070.00E-9          0  499.90HZ11000011856390424602393
102511:15:230.00E-9          0  499.94HZ11000011920388724552400
102511:44:220.00E-9          0  499.94HZ11000011840393624562393
102511:32:120.00E-9          0  499.95HZ11000011895396624562399
102511:13:230.00E-9          0  499.94HZ11000011843386524642432
102511:00:230.00E-9          0  499.95HZ11000011848395124962393
102511:18:230.00E-9          0  499.94HZ11000011856390324472394
102511:01:130.00E-9          0  499.94HZ11000011856393524512432
102511:28:430.00E-9          0  499.90HZ11000011908393524602391

102513:00:050.00E-9          0  499.94HZ11000011839391924552394
102512:15:170.00E-9          0  500.00HZ11000011920393524552428
102512:51:260.00E-9          0  499.94HZ11000011836390724802400
102512:36:360.00E-9          0  499.92HZ11000011880398424552394
102512:00:170.00E-9          0  499.90HZ11000011854388724962432
102512:00:170.00E-9          0  499.90HZ11000011854388724962432
102512:04:570.00E-9          0  499.94HZ11000011846396424462392
102512:00:170.00E-9          0  499.90HZ11000011854388724962432
102512:33:260.00E-9          0  499.96HZ11000011859390724542391
```

Figure 6.5.4 Hourly Record

```
102312:22:590.00E-9             0   499.94HZ11000011499358124432394
102312:23:090.00E-9             0   499.94HZ11000011492358324442399
102312:23:190.00E-9             0   499.93HZ11000011519358324432394
102312:23:290.00E-9             0   499.99HZ11000011562358324472191
102312:23:390.00E-9             0   499.94HZ11000011535358124962394
102312:23:480.00E-9             0   499.94HZ11000011535358324472394
102312:23:580.00E-9             0   499.94HZ11000011535358424802394
102312:24:080.00E-9             0   499.98HZ11000011563358324432393
102312:24:180.00E-9             0   499.96HZ11000011535358424962394
102312:24:280.00E-9             0   499.95HZ11000011562358324802392
102312:24:380.00E-9             0   499.93HZ11000011535358424472394
102312:24:480.00E-9             0   499.95HZ11000011559358224432392
102312:24:580.00E-9             0   499.98HZ11000011535358424962394
102312:25:080.00E-9             0   499.95HZ11000011535357924472394
102312:25:180.00E-9             0   499.94HZ11000011535358424802394
102312:25:280.00E-9             0   499.94HZ11000011535358124822392
102312:25:380.00E-9             0   500.00HZ11000011531357924962393
102312:25:480.00E-9             0   499.92HZ11000011535358424922392
102312:25:580.00E-9             0   499.91HZ11000011488358324472392
102312:26:080.00E-9             0   499.94HZ11000011535358424962394
102312:26:180.00E-9             0   499.94HZ11000011535358424802394
102312:26:280.00E-9             0   499.94HZ11000011551358324472392
102312:26:380.00E-9             0   499.94HZ11000011535361624882392
102312:26:480.00E-9             0   499.92HZ11000011535358324422392
102312:26:580.00E-9             0   499.97HZ11000011551358324402394
102312:27:080.00E-9             0   499.94HZ11000011535358424482392
102312:27:180.00E-9             0   499.95HZ11000011551358324422393
102312:27:280.00E-9             0   499.97HZ11000011535358424962394
102312:27:380.00E-9             0   499.94HZ11000011535358424482393
102312:27:480.00E-9             0   499.94HZ11000011512358424412416
102312:27:580.00E-9             0   499.94HZ11000011562360824432392
102312:28:080.00E-9          8676   499.94HZ11001011551358324882394
102312:28:180.00E-9             0   499.94HZ11000011559358324882392
102312:28:280.00E-9             0   499.94HZ11000011535358424402393
102312:28:380.00E-9             0   499.94HZ11000011523358224472394
102312:28:480.00E-9             0   499.94HZ11000011563358324882432
102312:28:580.00E-9             0   499.94HZ11000011535363224472393
102312:29:080.00E-9             0   499.97HZ11000011535358324802392
102312:29:180.00E-9             0   499.96HZ11000011551358124622392
102312:29:280.00E-9             0   499.92HZ11000011551357924962394
102312:29:380.00E-9             0   499.94HZ11000011520358324432394
102312:29:480.00E-9             0   499.99HZ11000011535358424432394
102312:29:580.00E-9             0   499.97HZ11000011535358424472392
102312:30:080.00E-9             0   499.94HZ11000011535358424412392
102312:30:180.00E-9             0   499.92HZ11000011535361624402399
102312:30:280.00E-9             0   499.90HZ11000011551360824422392
102312:30:380.00E-9             0   499.94HZ11000011563361624482394
102312:30:480.00E-9             0   499.93HZ11000011535358324472392
102312:30:580.00E-9             0   499.94HZ11000011495360824802400
102312:31:080.00E-9             0   499.94HZ11000011535363224882392
102312:31:180.00E-9             0   499.94HZ11000011535360824432392
102312:31:280.00E-9             0   499.94HZ11000011535358424962400
102312:31:380.00E-9             0   499.94HZ11000011551361624432392
102312:31:480.00E-9             0   499.94HZ11000011535358524962394
102312:31:580.00E-9             0   499.94HZ11000011551359924422392
102312:32:080.00E-9             0   499.94HZ11000011559359924882394
102312:32:180.00E-9             0   499.93HZ11000011535359924962392
102312:32:280.00E-9             0   499.95HZ11000011535358524962394
102312:32:380.00E-9             0   499.93HZ11000011535358424432394
102312:32:480.00E-9             0   499.94HZ11000011488363224442394
102312:32:580.00E-9             0   499.94HZ11000011535358524432415
102312:33:080.00E-9             0   499.94HZ11000011551359124402392
102312:33:180.00E-9             0   499.98HZ11000011527361224402394
102312:33:280.00E-9             0   499.94HZ11000011535359924432392
```

Figure 6.5.5 Error Event Record

6.5.3 Optical Power Versus Vibration

Figures 6.5.6 to 6.5.11 show the relationship between optical power and vibration. These scatter plots indicate that the optical power variations were within the limits of the meter's accuracy. The vibration as recorded at the MCR rack did not indicate that there was a direct relationship between optical power and vibration.

6.5.4 Optical Power Versus Temperature

Figures 6.5.12 to 6.5.15 show the plots of optical power versus temperature. Once again, the optical power variations over the recorded temperature range are with the accuracy limits of the power meter. From this, no relationship could be identified between the temperature and the optical power.

A manually recorded plot of optical power and temperature versus time for the LD cable is shown in figure 6.5.16. The significance of this plot is that the temperature passes through the freezing point and that there is no variation in the optical power. The optical power remained constant over the -11 C to +4 C range for the four day period. This test was conducted after the sea trial period, when the cables had had more than a year of exposure to the environment.

6.5.5 Error Events Versus Sensor Data

Plots of the data from the four sensors versus time are shown in figures 6.5.17 to 6.5.20. In each of these plots, the data shown is for the time five minutes before and five minutes after a loss of synchronization by the BERTS which results from data or clock errors. These plots do not conclusively indicate the cause of the loss of synchronization. In these plots, the sensor data scale is for reference only.

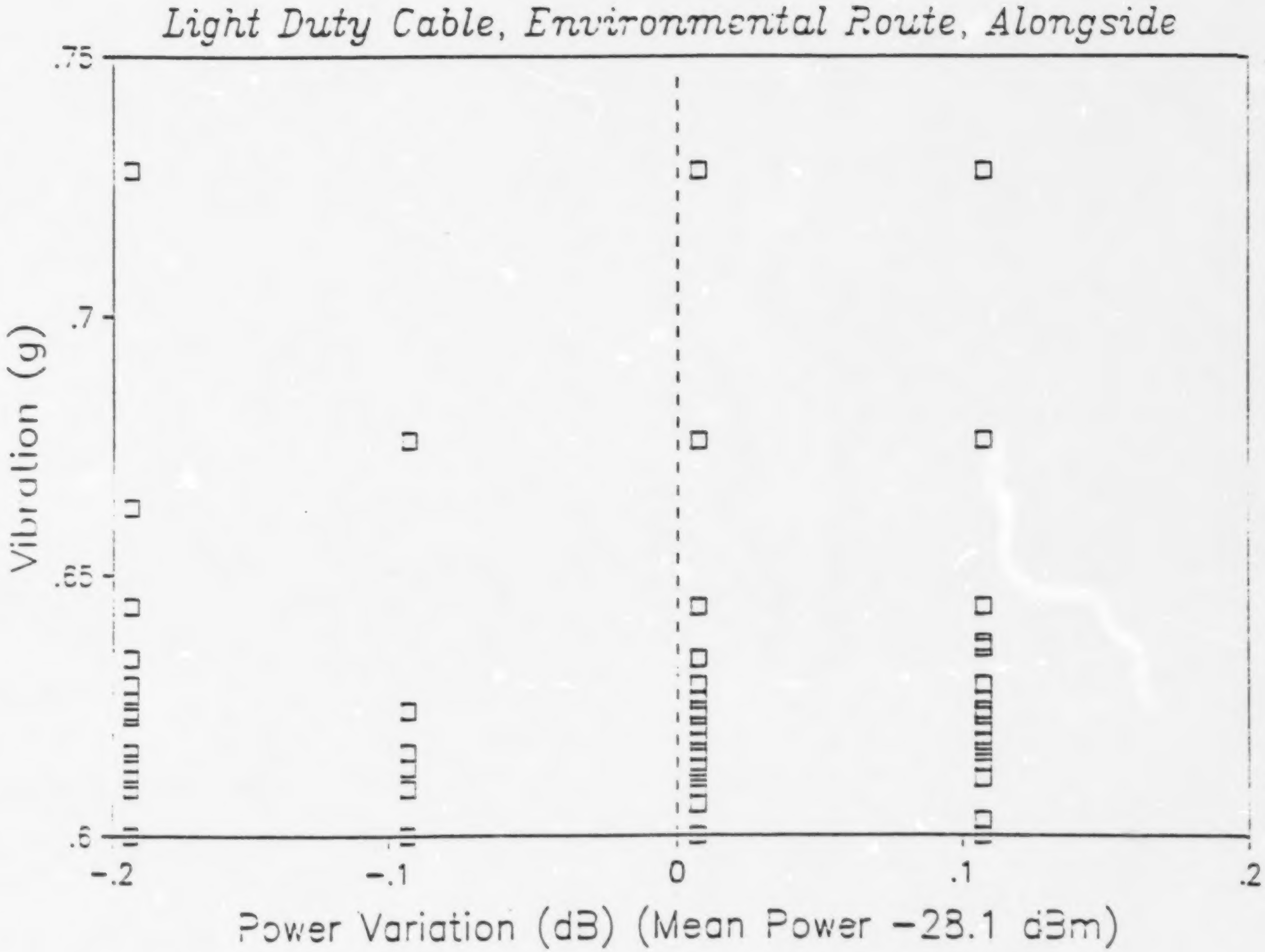


Figure 6.5.6 Optical Power Variation vs Vibration

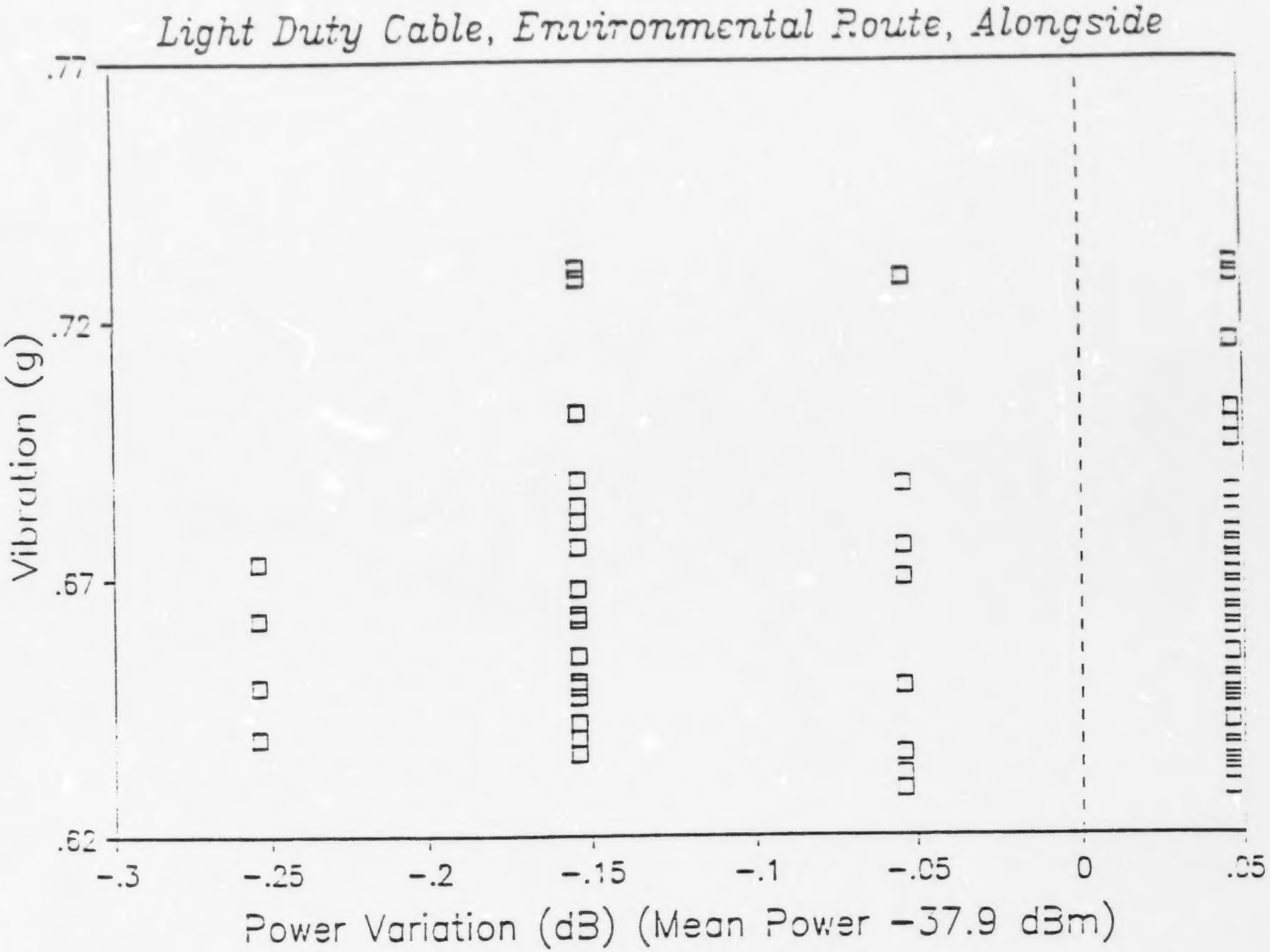


Figure 6.5.7 Optical Power Variation vs Vibration

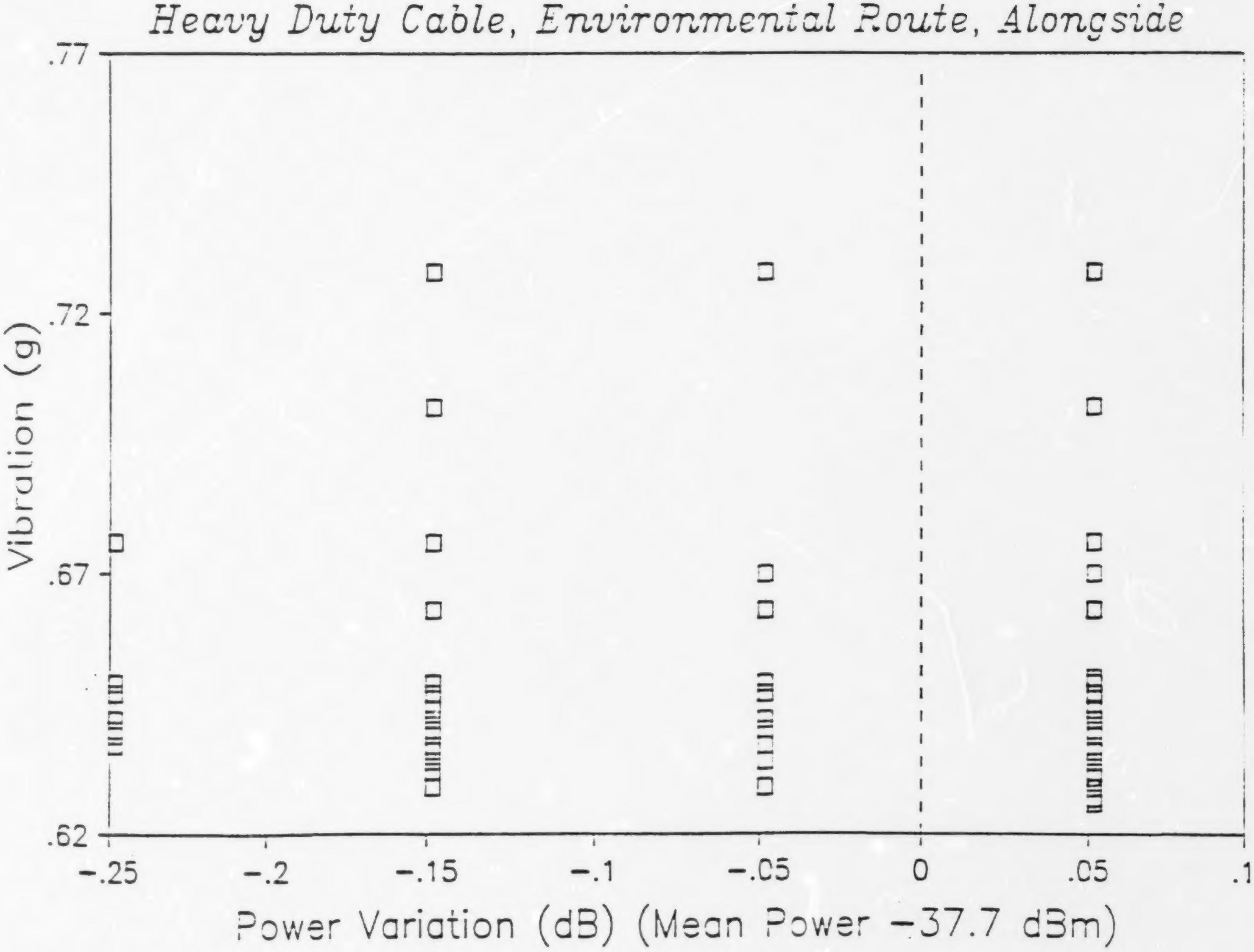


Figure 6.5.8 Optical Power Variation vs Vibration

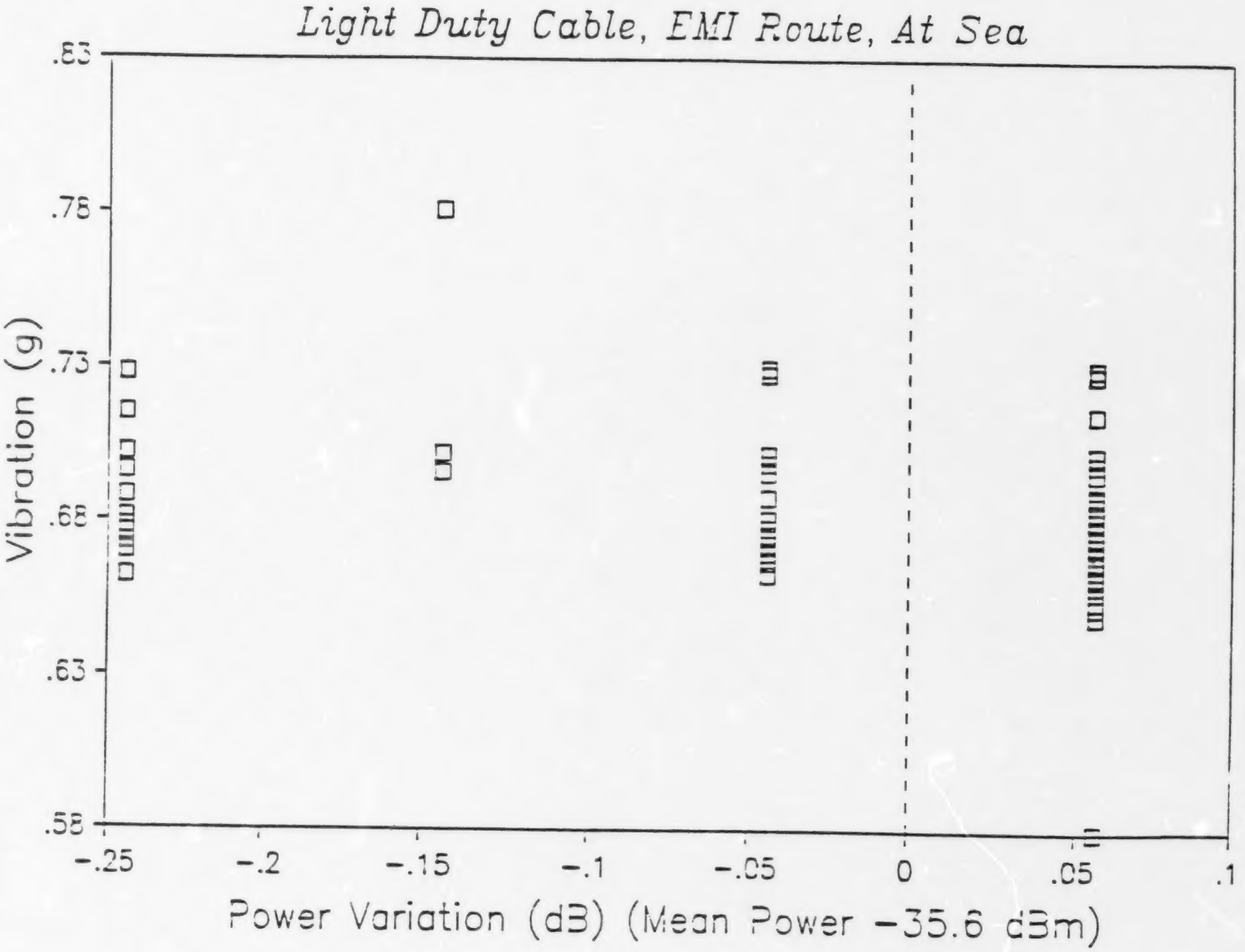


Figure 6.5.9 Optical Power Variation vs Vibration

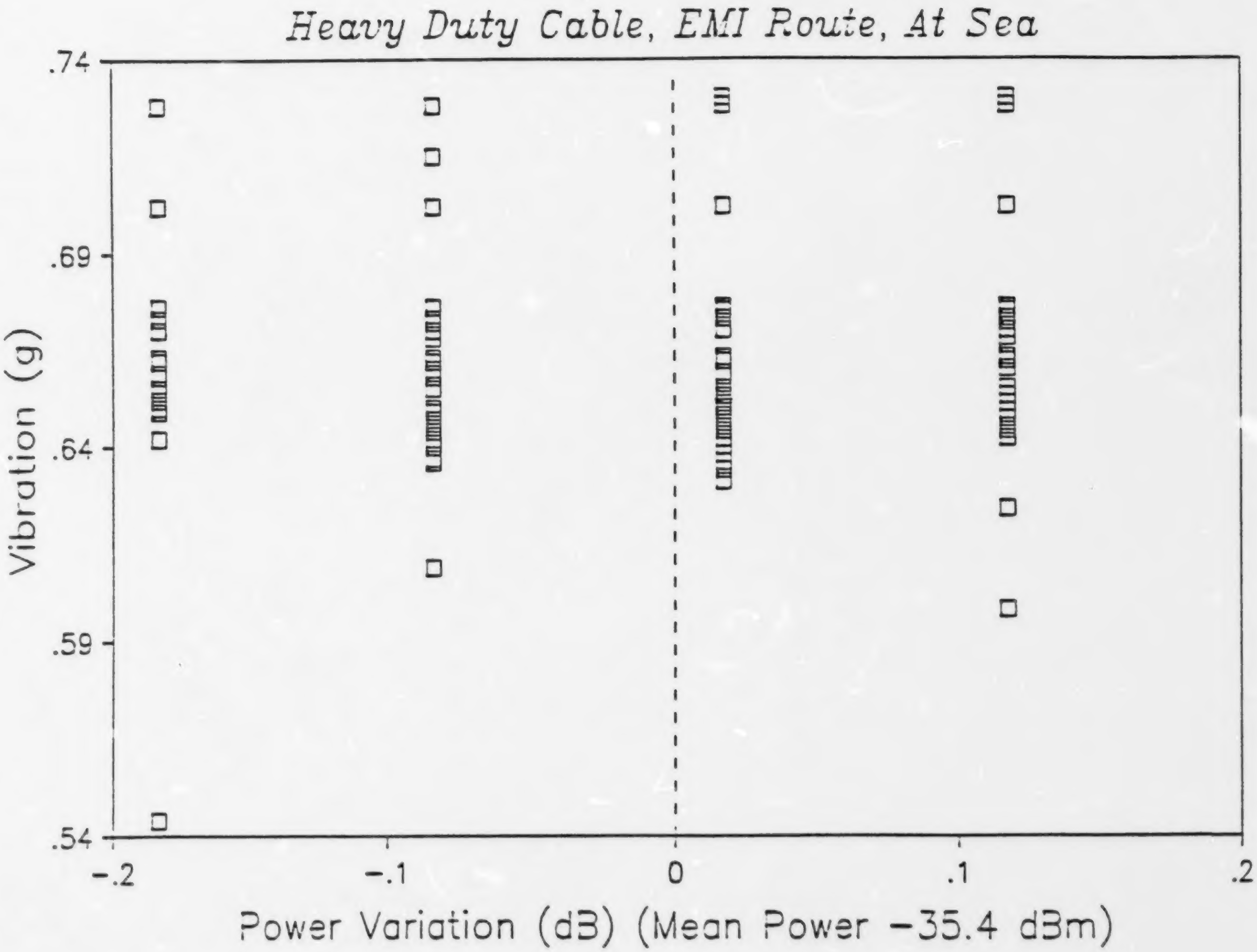


Figure 6.5.10 Optical Power Variation vs Vibration

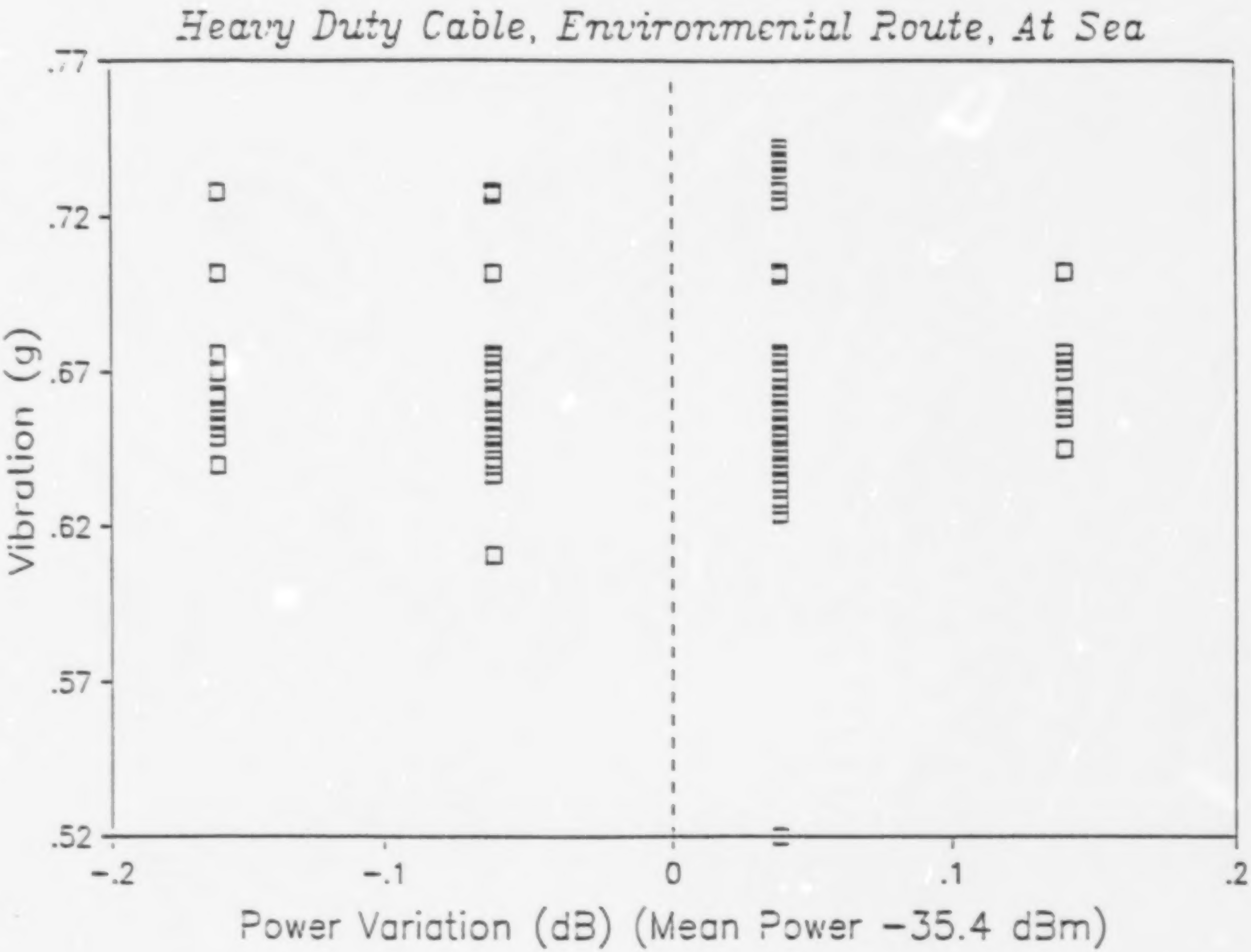


Figure 6.5.11 Optical Power Variation vs Vibration

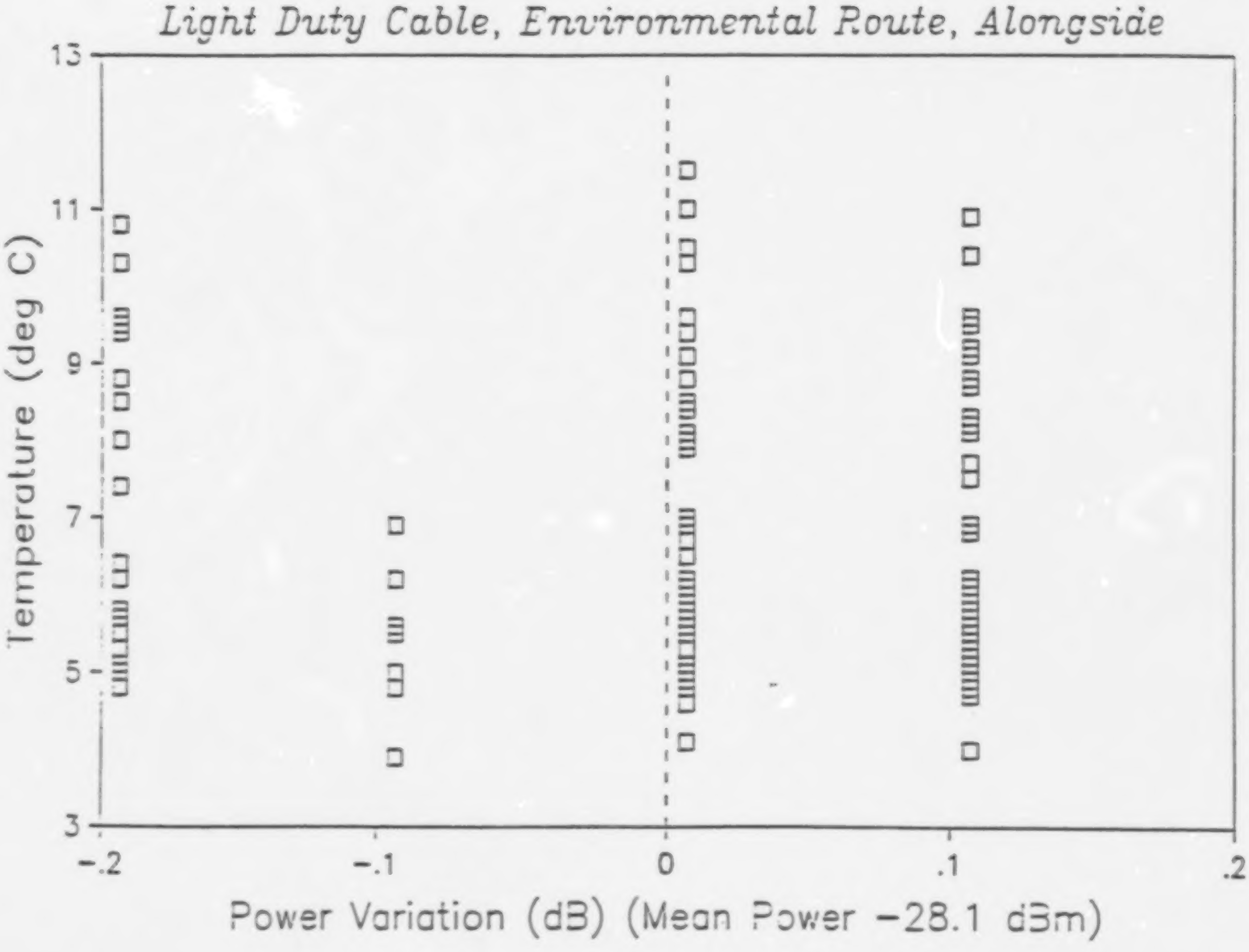


Figure 6.5.12 Optical Power Variation vs Temperature

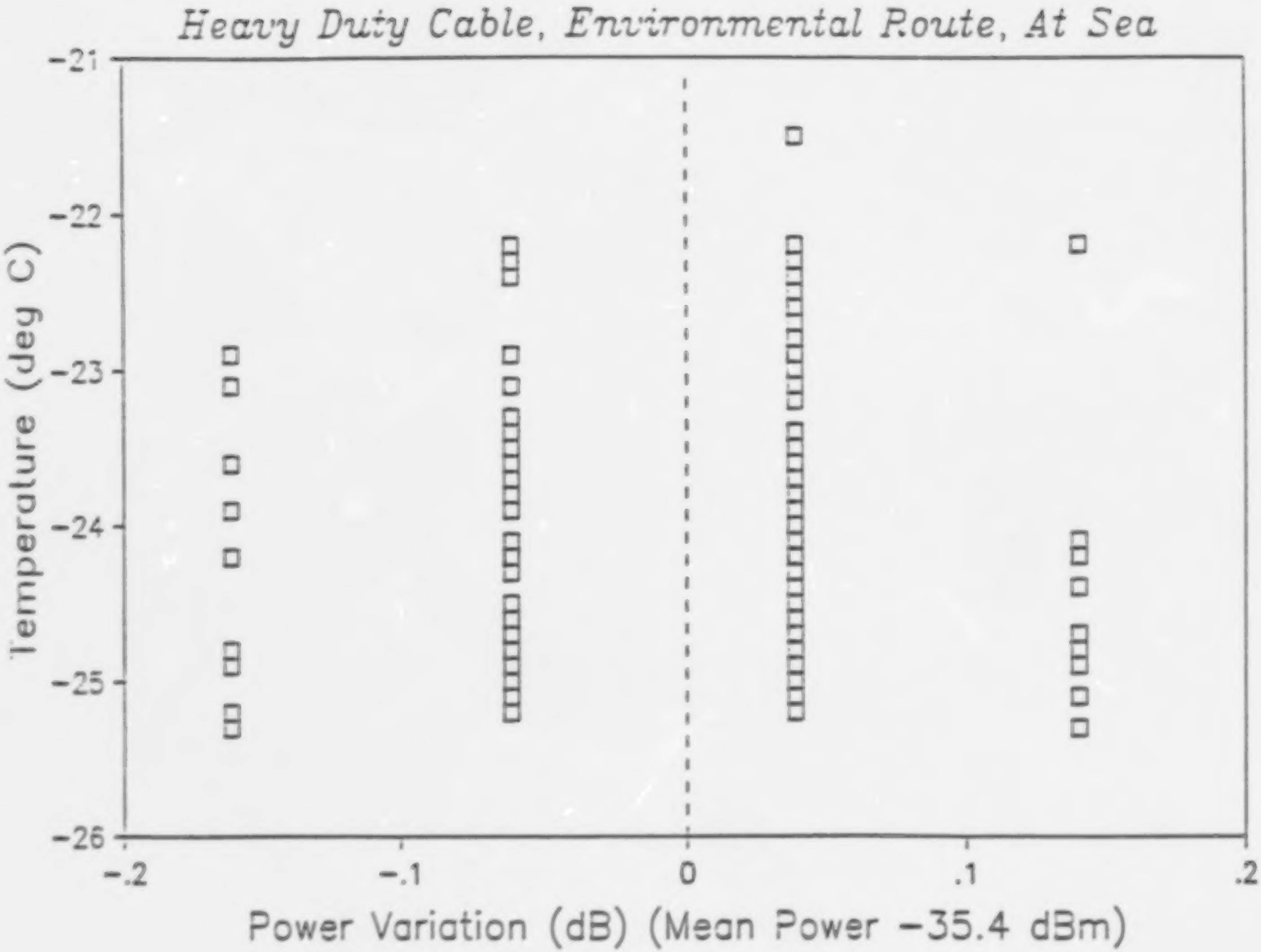


Figure 6.5.13 Optical Power Variation vs Temperature

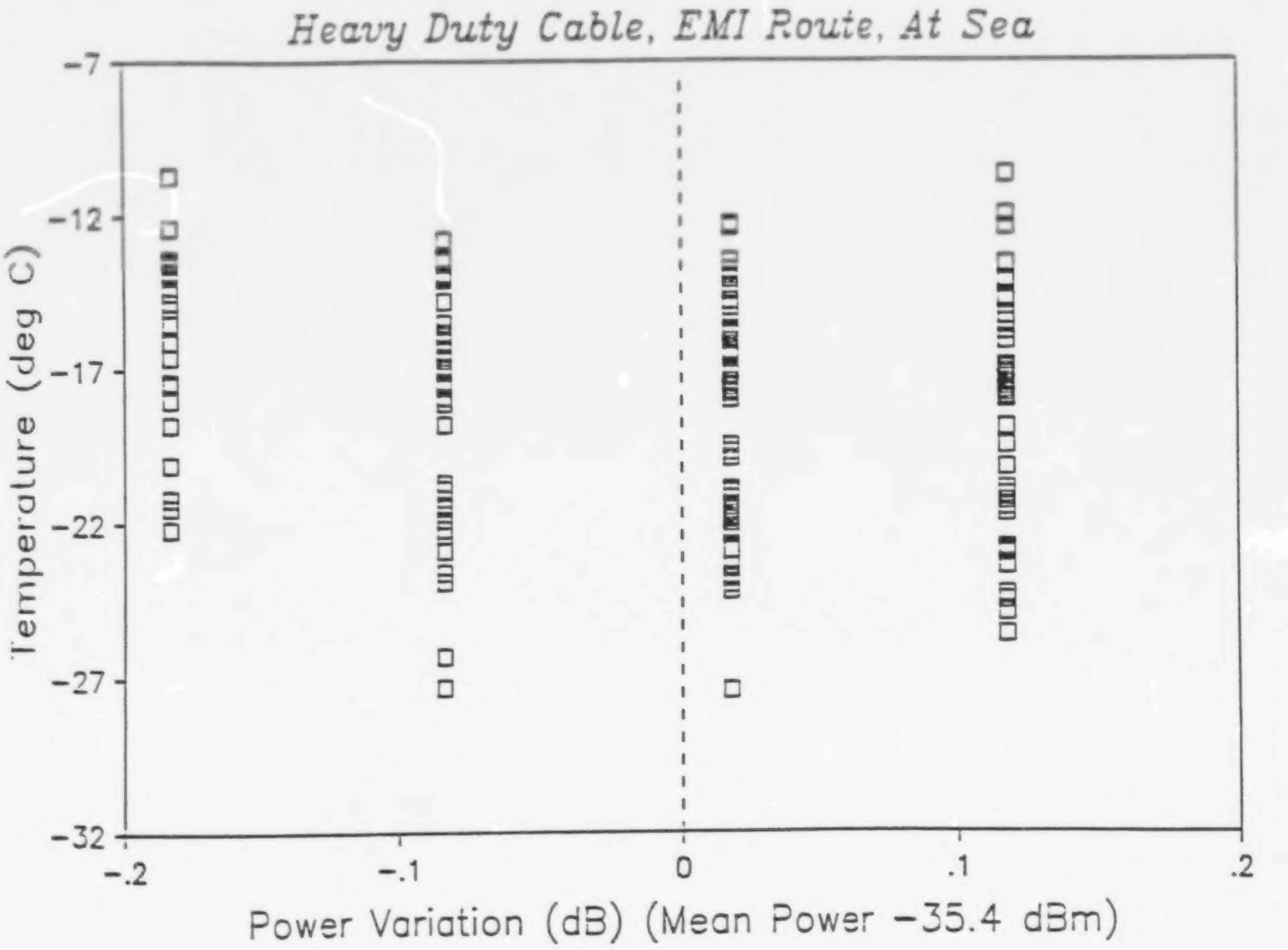


Figure 6.5.14 Optical Power Variation vs Temperature

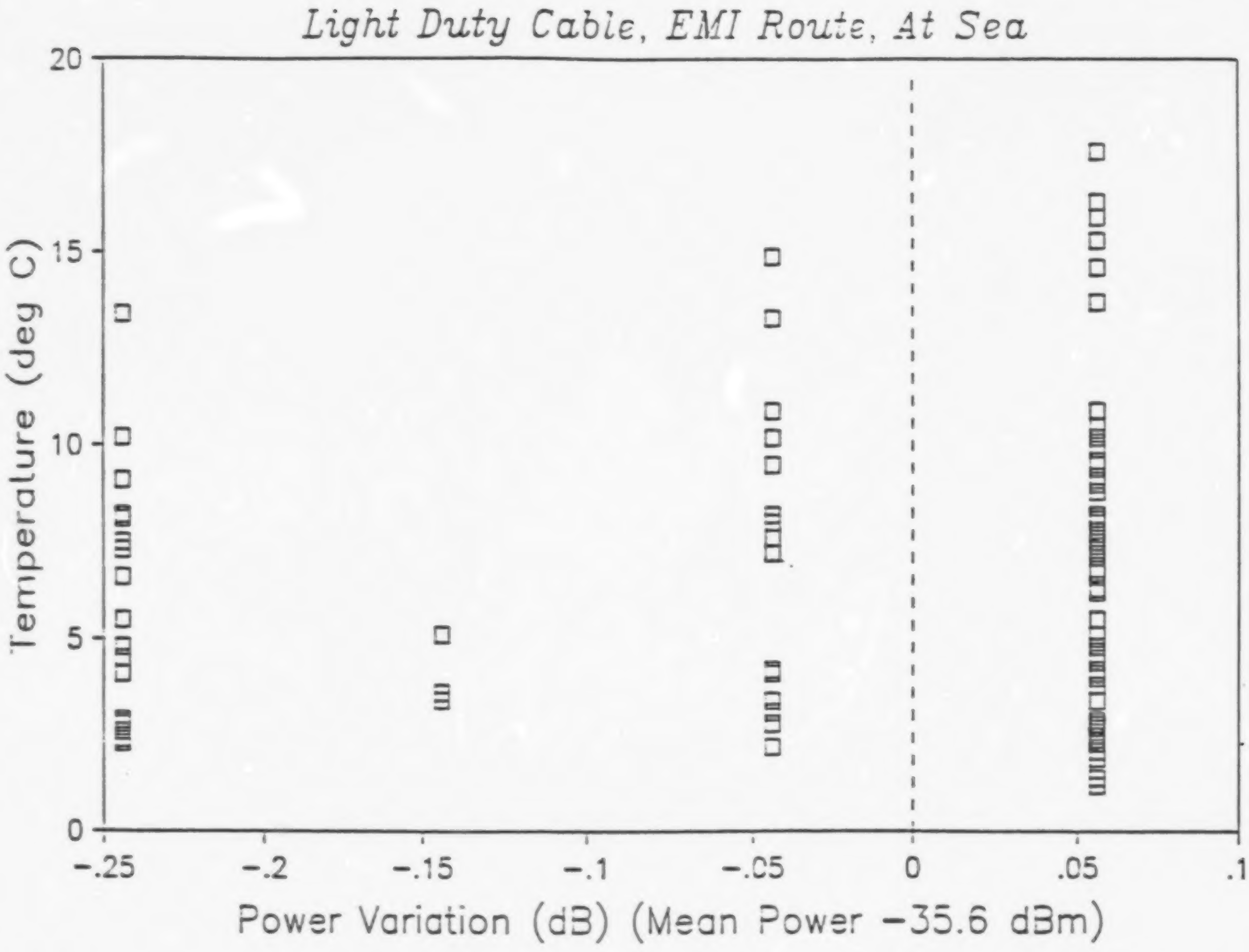


Figure 6.5.15 Optical Power vs Temperature

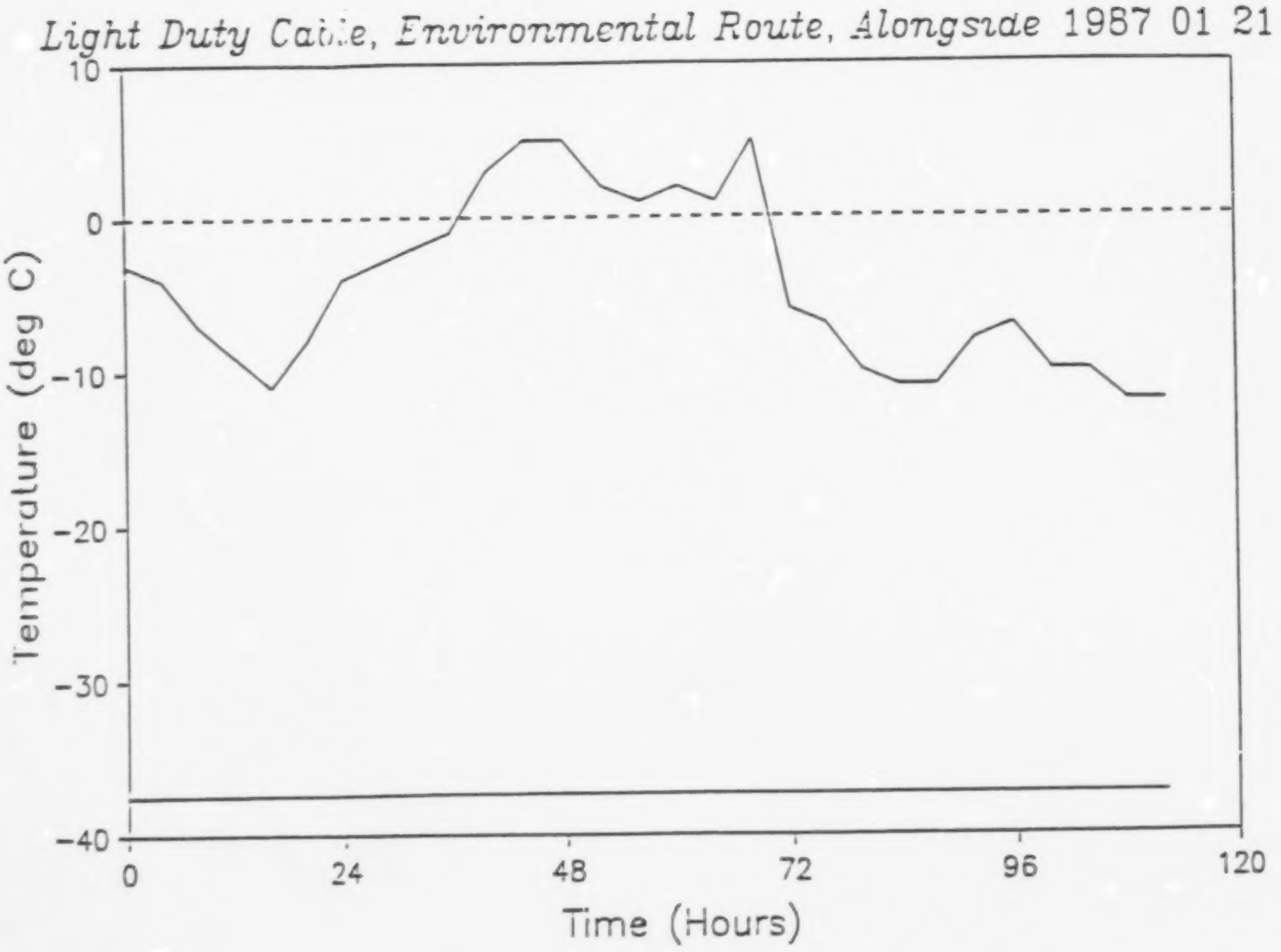


Figure 6.5.16 Optical Power Variation vs Temperature

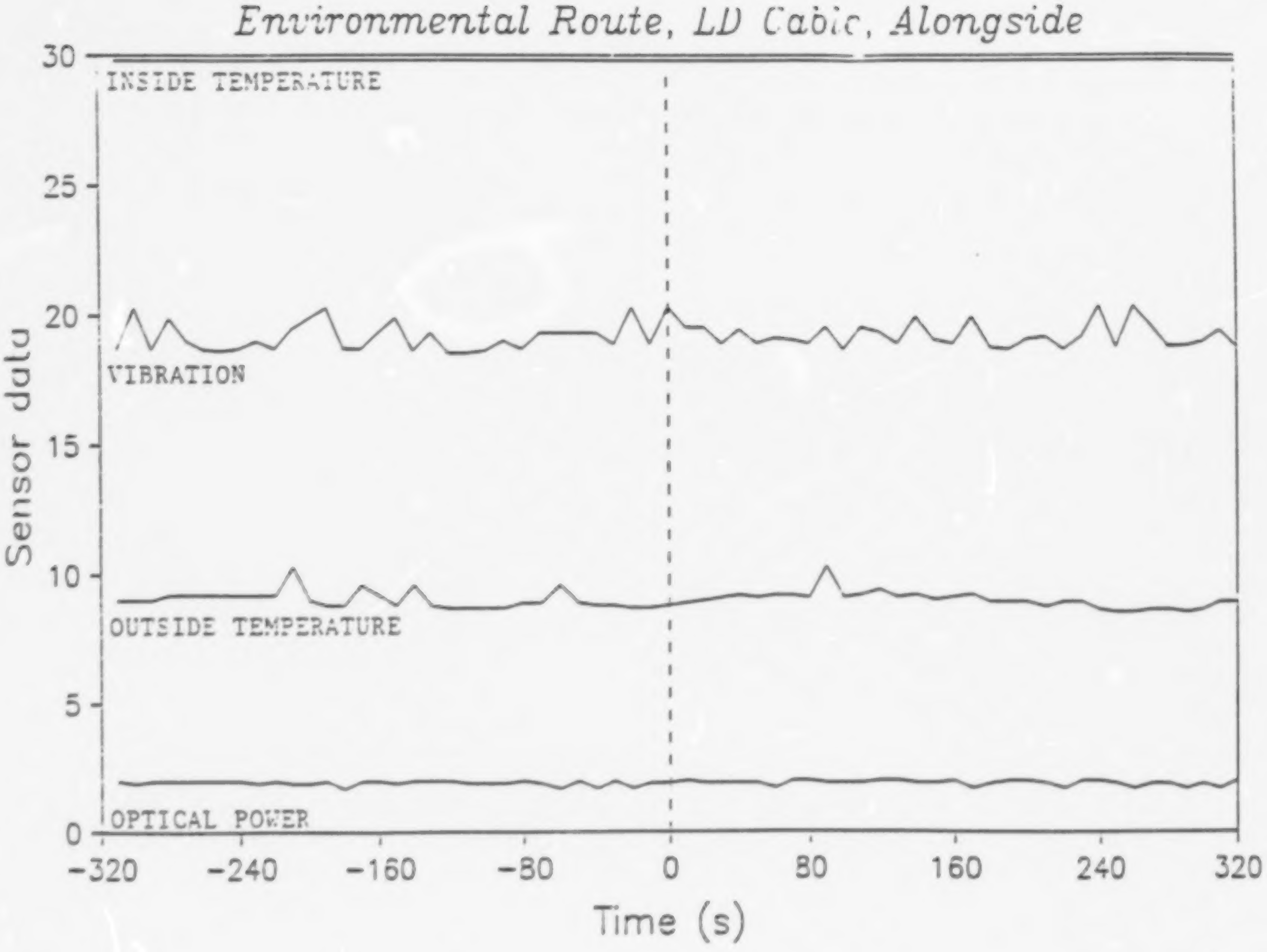


Figure 6.5.17 Sensor Data During an Error Event

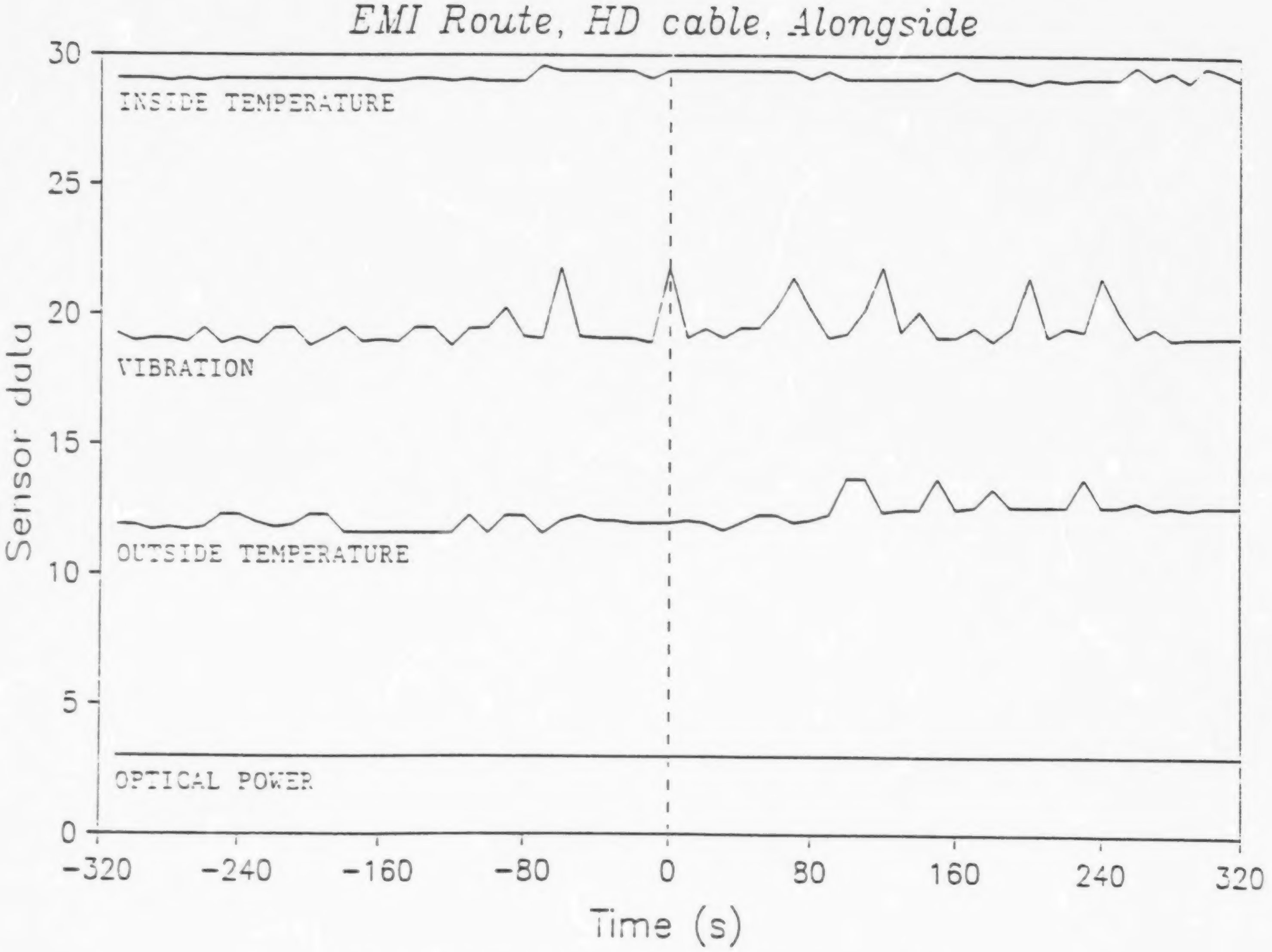


Figure 6.5.18 Sensor Data During an Error Event

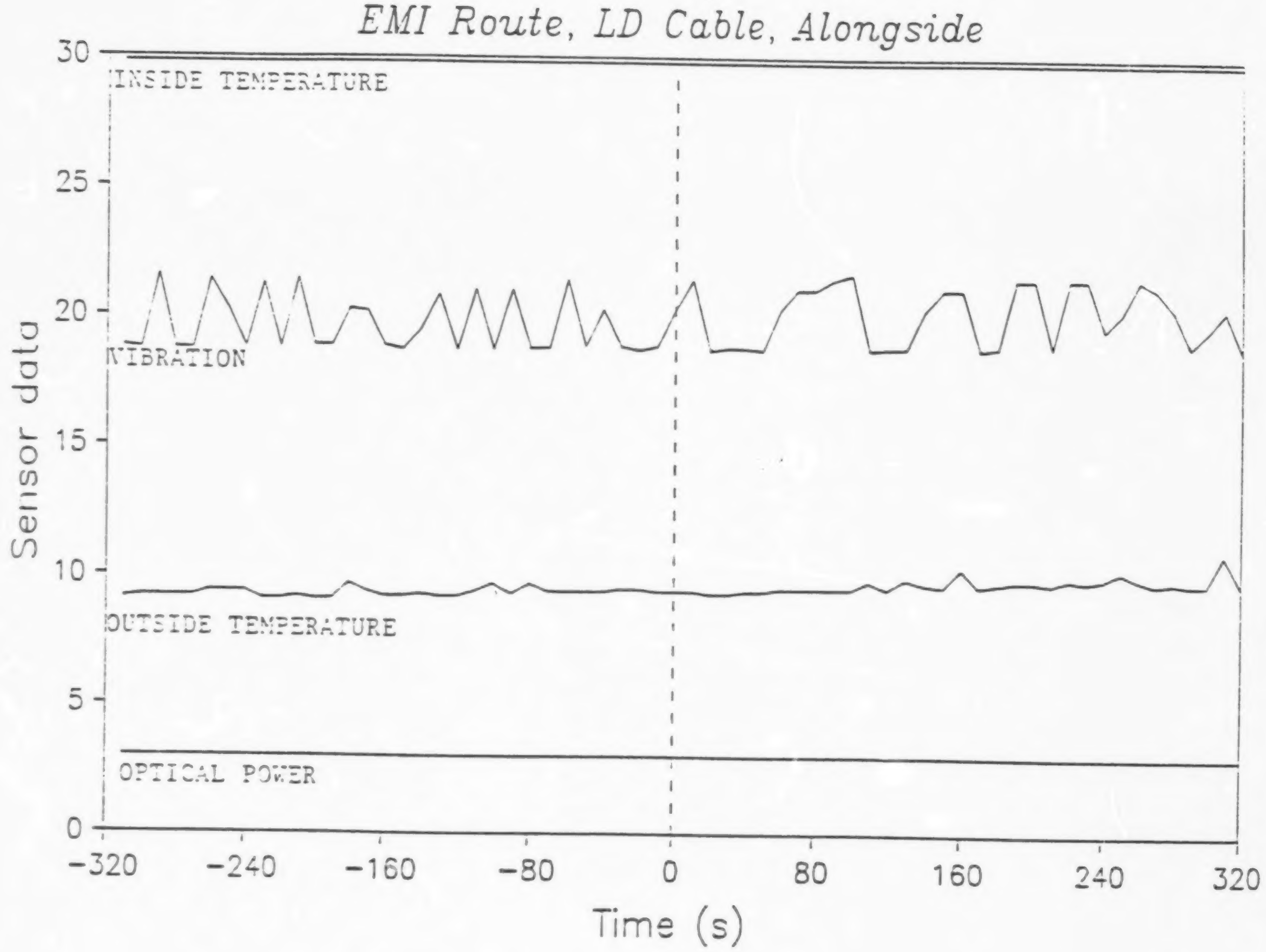


Figure 6.5.19 Sensor Data During an Error Event

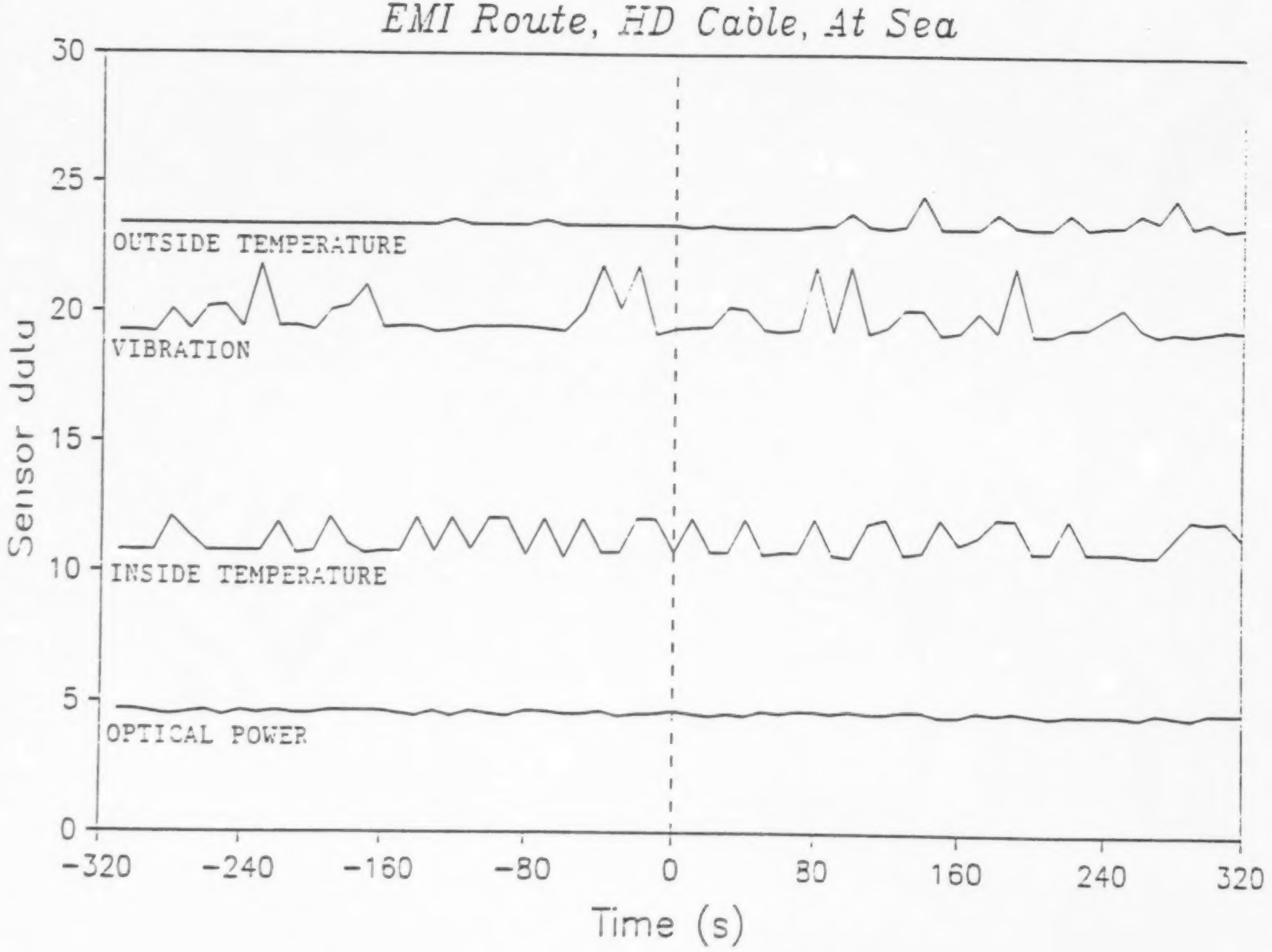


Figure 6.5.20 Sensor Data During an Error Event

6.6 Post Sea Trial Testing

Post sea trial testing served to provide data for before and after comparisons. These tests included OTDR scans of all fibres, optical source power measurements, link insertion loss measurements and also a visual inspection of the installed system.

6.6.1 OTDR Tests

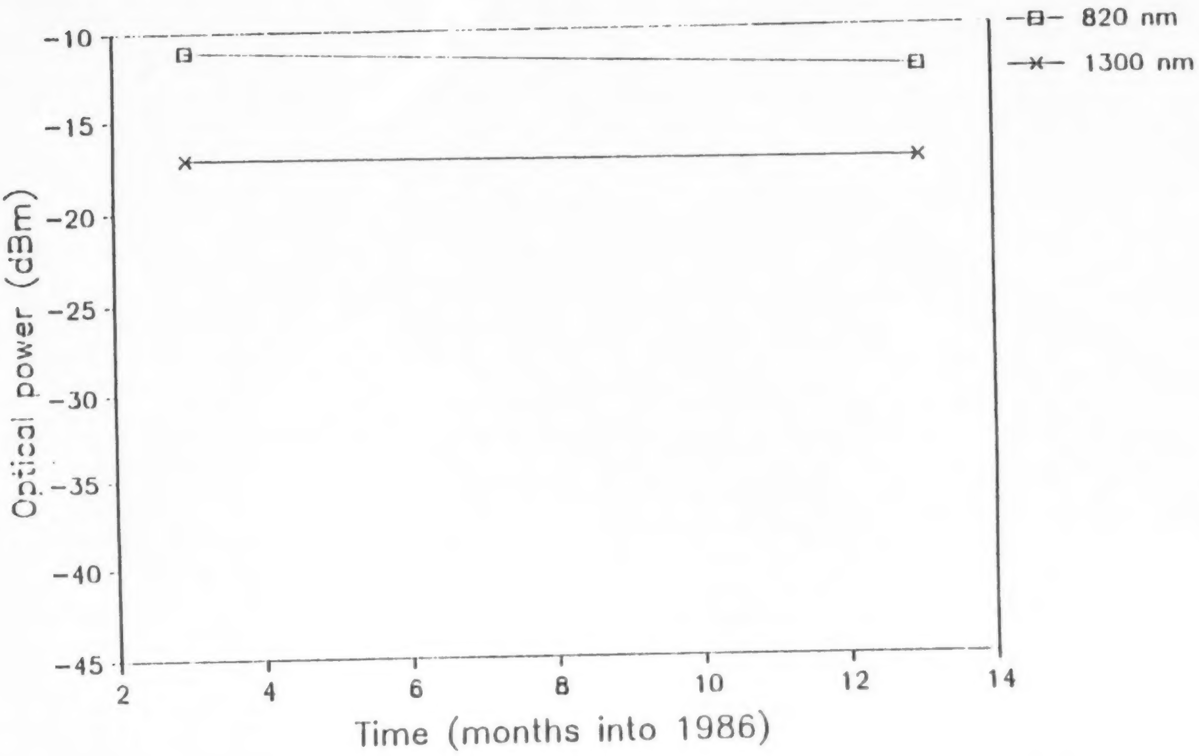
As with the original OTDR tests, the result of these tests are recorded as photographs. Table 6.3.1 includes a sample of some of the test results from the post sea trial testing.

6.6.2 Insertion Loss Test

Insertion loss measurements were made at both wavelengths and along all of the fibre routes except those requiring transmissions from the lower boiler room (LBR) node. The reason for this exception was the greatly reduced output power from the transmitters in this node. Once again, the video test signal was the quiescent output level from the video transmitter. The test signal for the digital transmitters was a $2^{15}-1$ pseudo-random pattern. Bench testing demonstrated that this signal format produced an average of 0.1 dB less output power from a transmitter when compared to the output using a 50% duty cycle TTL signal at the same frequency. The results of these measurements are given in Appendix C, "Installation Test Results."

6.6.3 Source Power Test

The before and after transmitter output power measurements for the MCR, bridge, and LBR transmitters are given in figures 6.6.1, 2 and 3 respectively. When interpreting these plots, one should be aware that not all of the components were active during the alongside and sea trial test periods. On the digital side, the LBR and bridge transmitters were used alternatively and the MCR receiver was the only active digital receiver. The MCR video transmitter and the bridge video receiver formed the only active video link. The MCR and LBR video transmitters were, however, on at their quiescent level and their receivers were receiving the signal broadcast by the MCR transmitter, although their outputs were not monitored.

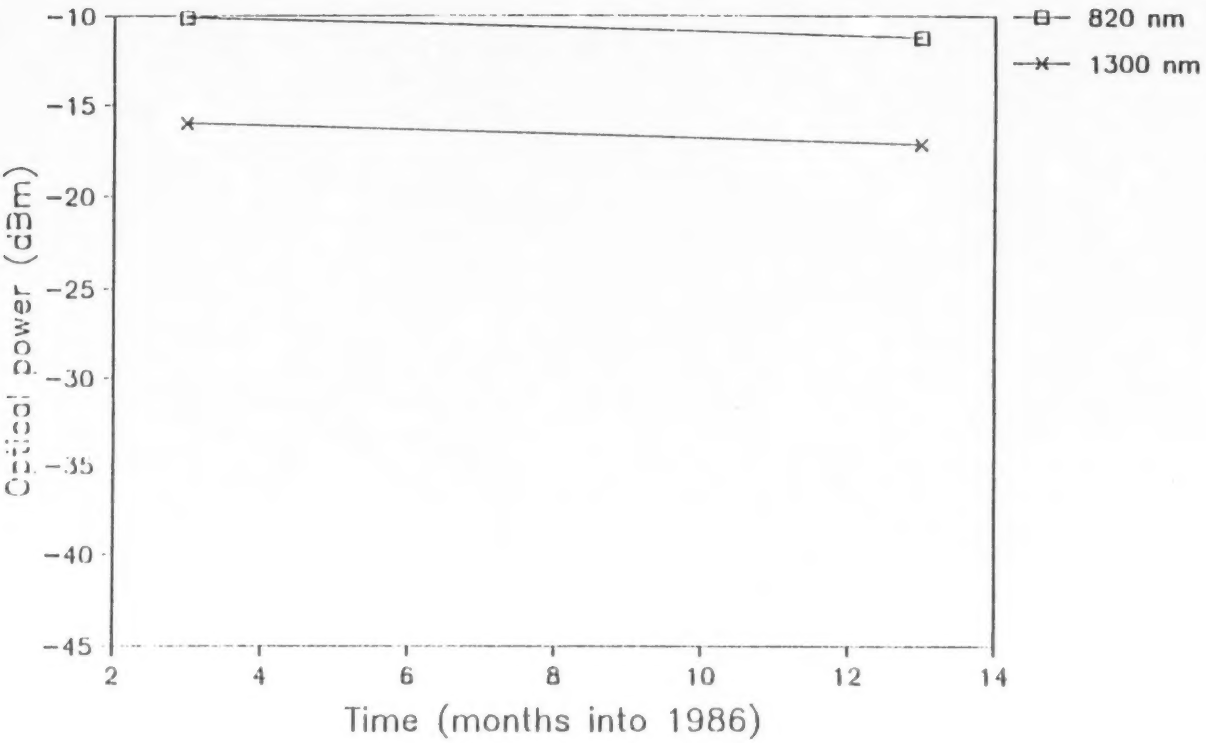


- VIDEO POWER MEASURED AT THE OUTPUT OF THE SYSTEM WDM

- DIGITAL POWER MEASURED AT THE END OF A 0.5 m PIGTAIL

- DIGITAL TRANSMITTER NOT USED

Figure 6.6.1 Transmitter Power vs Time - MCR Transmitter



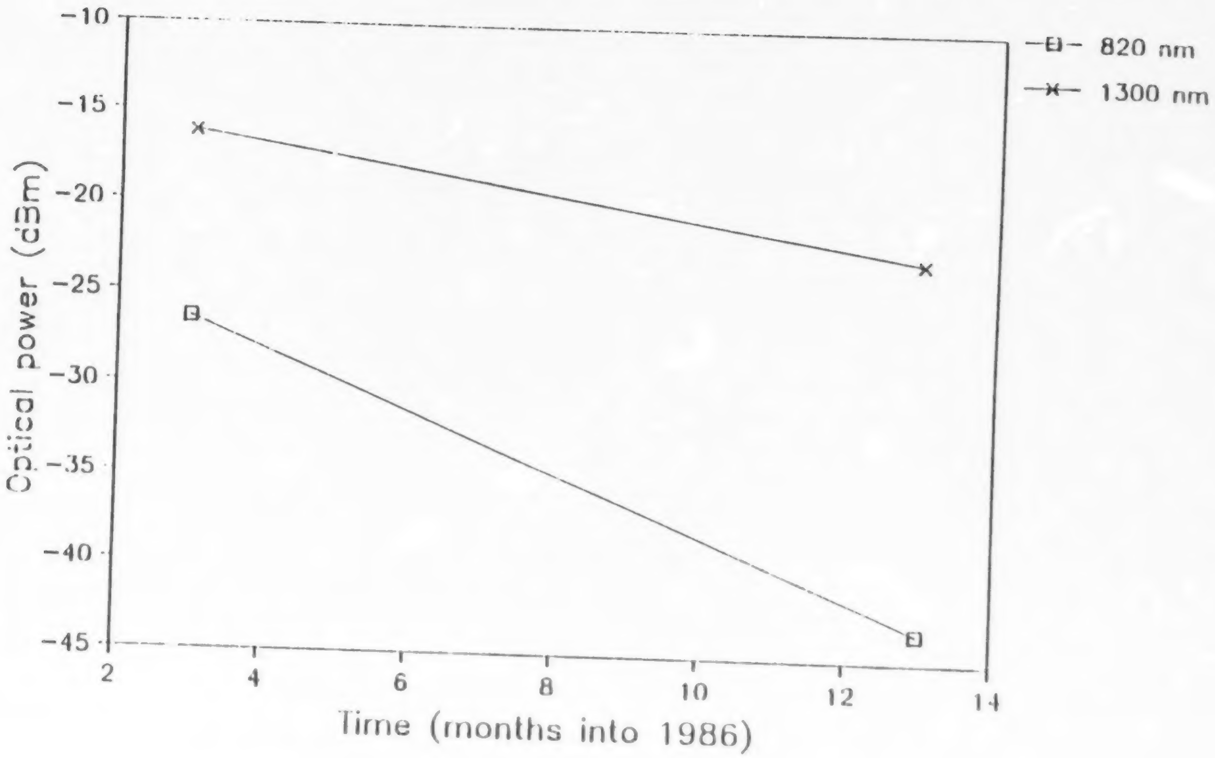
- VIDEO POWER MEASURED AT THE OUTPUT OF THE SYSTEM WDM

- DIGITAL POWER MEASURED AT THE END OF A 0.5 m PIGTAIL

- MECHANICAL SPLICE

- VIDEO TRANSMITTER NOT USED

Figure 6.6.2 Transmitter Power vs Time - Bridge Transmitter



- VIDEO POWER MEASURED AT THE OUTPUT OF THE SYSTEM WDM
- DIGITAL POWER MEASURED AT THE END OF A 0.5 m PIGTAIL
- VIDEO TRANSMITTER NOT USED
- EXPOSED TO TEMPERATURE AND HUMIDITY EXTREMES

Figure 6.6.3 Transmitter Power vs Time - LBR Transmitter

The transmitter output power level plots show a decrease in output power over the year between the beginning and the end of the test period. This is consistent with published literature on the aging of optical sources. Both the long (digital) and short (analog) wavelength transmitters in the LBR node show an output which is much more reduced than the outputs from the other transmitters in the system. This is explainable when the history of that node is taken into account. On more than one occasion, the node was subjected to a steam bath. On one of these occasions, a pipe plug, located within two meters of the node and slightly below it, blew out, filling the space with steam. Even without the added humidity of steam leaks, the temperature inside the node enclosure, with the front panel removed for access, was measured at more than 50 degrees Celsius.

When operating at elevated temperatures, the life expectancy of LED sources is reduced. These test results confirm what was expected, albeit in a more extreme condition than was anticipated.

6.7 Video Performance

Evaluation of the performance of the video system was mostly subjective. The concept of the video was well received by the ship's crew despite some of the limitations on the system. These limitations were mainly the result of the incompatability of the video camera as supplied, with the lighting of the working environment (it was a low-light-level camera). See table 6.7.1 "Video Performance."

The watch officers recorded the quality of the video performance regularly. When the lighting conditions were within the operating limits of the camera, the quality of the video was consistently good. There was no observed effect of crosstalk with the digital and video transmissions. Also, there was no observed or measured effect of the video signal on the performance of the digital system. The isolation of the two wavelengths, as provided by the use of the wavelength division demultiplexers, was effective in keeping the two systems separate.

Table 6.7.1 Video Performance

- VIDEO SYSTEM WELL RECEIVED BY CREW
- PERFORMANCE LOGGED REGULARILY BY CREW WAS ALWAYS FOUND TO BE GOOD DESPITE LIMITATIONS OF LOW LIGHT CAMERA
- CROSSTALK WAS NOT OBSERVED - WDM PERFORMED ACCORDING TO ACCEPTANCE TESTS

6.8 Post Sea Trial Examination

6.8.1 Visual Inspection

As part of the post sea trial inspection, a visual inspection of the system was conducted. A report on this inspection is given in Appendix D. The most significant finding of this inspection was that the adhesive holding the pigtail from the splice to the digital transmitter in the LBR had broken free from the optical assembly board and splice enclosure. Further investigation revealed that the transmitter end of this pigtail had broken free from the transmitter housing. This pigtail may have been subjected to high stress load which rendered it susceptible to damage from low level loading. Eventually, the fibre in this pigtail sheared off at the point of connection to the transmitter.

6.8.2 Pigtail Damage

Before the LBR digital transmitter fibre actually broke, output power measurements were made at the output of the optical assembly. From the transmitter the optical signal went through the damaged pigtail, through a fusion splice, and through a WDM. An SMA connector on the end of the output pigtail from the WDM was connected to the optical power meter. This measurement showed an output power which was more than 20 dB below the expected level. When the transmitter was removed and the fusion splice was broken, the output power as measured from the transmitter pigtail was significantly improved. This leads to the conclusion that either the WDM or the fusion splice was the source of the power loss.

6.8.3 Optical Inspection

A detailed optical analysis of the status of the system identified the mechanical splice in the bridge node as the source of approximately 5 dB decrease in the output power from the digital transmitter of the bridge node when compared with the original output power measurement. Microscopic examination of the elastomeric insert of the GTE 7700-0014-000 splice assembly used for that splice did not reveal the presence of any broken fibre or foreign material inside the splice. The increase in insertion loss may be attributed to an increase in the fibre end separation within the splice.

Independent studies into splicing techniques have shown that there have been some reported problems with earlier GTE splices of which the 7700-0014-000 is typical. GTE has since modified their splice packs to include a UV cured adhesive to help stabilize the splice.[2]

7.0 INSTALLATION/CHECKOUT PRACTICES

7.1 Areas of Discussion

During the installation and checkout phases there were several items of concern which are worthy of further discussion, as they will benefit others doing similar installations. These items include:

- effect of polishing on the end finish of 100/140 um fibre
- SMA connector type compatibility
- SMA to SMA alignment
- epoxies used for cable termination
- cable support
- connection optimization
- connector heating
- cable installation technique
- cleanliness

7.1.1 Fibre Cracking

All of the cable terminations were made on site. Under normal conditions, using hand polishing techniques, a certain percentage of unacceptable terminations are expected. In the case of this shipboard installation, the number of unacceptable terminations was higher than normal. Microscopic investigation revealed the presence of axial cracks as the cause of the high losses. This is termed the "Mercedes" crack, as it often takes the form of a three-pointed star. Although we had not read of this problem, subsequent inquiries showed that it was not unknown. This led to an investigation of the type of epoxies used and to a re-evaluation of the polishing techniques. Various types of epoxies, including a fast cure, five minute type and slower cure TRA-CON F113 and F113 SC, as well as a heat cure TRA-CON BB-F230 epoxy were tested. This testing indicated that the cracking problem was not dependent on the epoxy type.

The polishing technique was also investigated as the source of the fibre cracking problem. Although this was not identified positively as the cause of the problem, it was found that by using extra precautions, the number of unacceptable terminations could be reduced to a lower than average percentage. Having found a way around this problem, the unacceptable terminations were replaced.

In the course of our investigation, we had contacted the manufacturers of both the epoxies and the connectors to get their advice. In response to these inquiries, we received a copy of a document published by Optical Fibre Technologies (OFTI) Inc. of Billerica, MA (Appendix E). In summary, the document recognized the inherent problem with end cracking of 100/140 graded index fibre and attributes it to the dopant characteristics of the core material of the fibre.

7.1.2 SMA Type Compatability

One of the objectives of this project was to evaluate a variety of optical components and component types. For that reason, SMA connectors from two different manufacturers were integrated into the system design. Amphenol 906-122-5000 and OFTI 255 SA RB-2 were used. OFTI had claimed that their connector was compatible with the Amphenol 906 series SMA connectors. When connectors of these types were mated in an Amphenol 905-120-5003 SMA-SMA bushing, insertion losses were found to be, on occasion, more than 2 dB higher than when two Amphenol connectors were so mated. Investigation of this increase in insertion loss found that it was to do with incompatibilities between the connectors from the two manufacturers. In some cases the increased losses were not acceptable and the OFTI connectors were replaced. In other cases, the insertion losses were not unacceptably high so these connectors were not replaced.

The Amphenol connectors, which are stainless steel, showed no sign of degradation at the time of the post sea trial visual inspection. Although no increase in insertion loss could be attributed to oxidation of the connector tips, the OFTI connector tips, which are made of aluminum, showed signs of oxidation. In certain circumstances, this process could lead to fouling of the fibre end and an increase of the insertion loss. Product data sheets on both of these connector types and the bushing are given in Appendix E.

7.1.3 SMA to SMA Alignment

During the installation and testing of the system, it was necessary to repeatedly make and break the optical links at the SMA-SMA bushings. These connections include Delrin alignment sleeves which straddle the noses of the mating connectors to provide positive axial alignment. Testing of these devices revealed that with repeated usage, the alignment sleeves stretched radially so that the insertion loss and repeatability of the connection suffered. Insertion loss increases of about 0.05 dB were observed after about 5 mating cycles and of about 0.1 dB for more than 10 cycles. Based on these findings, it is recommended that these alignment sleeves be replaced after 5 cycles if the increases in insertion loss cannot be tolerated.

Half-length Delrin alignment sleeves provided with both the Amphenol and the OFTI connectors were observed to increase the reliability of repeated connectoring to SMA receptacles and their use is recommended. Unlike the full length alignment sleeves where reentry is required with each use, these alignment sleeves remain fixed to the connector tip so that they do not stretch with reconnectoring and, thus, do not require replacement so frequently.

7.1.4 Epoxy Concerns

In addition to the concerns for connector epoxies mentioned in 7.1.1, there were some other epoxy related concerns. The OFTI publication referenced in section 7.1.1 attributed some of the fibre cracking problem with the heat required to cure some types of epoxies.

Our own experience has initiated some additional concerns for epoxies. A viscous epoxy such as most 5 minute epoxies often contains gas bubbles trapped in the epoxy when it is mixed. These bubbles often remain trapped as the epoxy cures, leaving voids. This can result in lack of proper support for the fibre in the connector and premature failure due to uneven stress distribution. In addition there is concern that a viscous epoxy may not properly fill the connector cavity with the same detrimental results.

Less viscous epoxies can be injected into the connector cavities using a syringe. Often these more fluid epoxies are of the slow cure type. One of the problems with low viscosity, slow cure epoxies is that they can leak out of the connector before they set. Not only does this result in a deficiency of epoxy in the connector, but, as it runs out, it can cause other parts of the connector to be inadvertently bonded.

Low viscosity epoxy is also more likely to wick along the cable than more viscous type. The result is that the cable becomes more rigid than was intended and more importantly, it can result in local stress points along the fibre in close vicinity to the connector. This condition can result in an increase in signal attenuation and/or premature failure.

7.1.5 Cable Support

An all-dielectric cable, such as is the case with many fibre optic cables, can be quite limp. A limp cable requires more support than is afforded standard electrical cables. When deciding on the cable support mechanism and extent, the self supporting characteristics of the cable should be taken into account.

7.1.6 Connector Optimization

SMA to SMA connections at bushing brackets can be optimized by rotating the two connectors about their respective axes until minimum attenuation is observed. The connector can then be tightened in position. [1] Monitoring the attenuation as the connectors are tightened will insure that the proper alignment is maintained as well as providing the operator with an indication of when the proper tightness is achieved. If the connectors are tightened too much, a loss increase of 0.2 to 0.3 dB will normally be observed.

7.1.7 Connector Heating

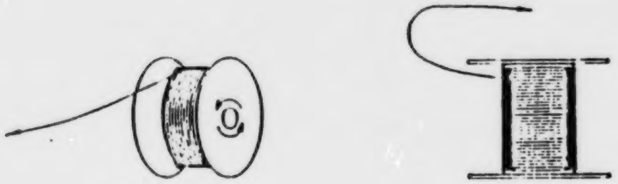
Heating of a connector can be necessary for two reasons, the first of which is to cure some types of epoxies. The preferred method for applying heat for this purpose is with a temperature regulated, curing oven. Alternatively, a heat gun can be used with due caution. The second reason for heating a connector is to apply a heat shrink sleeve over the cable to connector interface. When heat is applied, care must be taken not to damage the cable jacket material by overheating.

7.1.8 Cable Installation

Research into the proper techniques for cable installations, be they fibre optic or otherwise, revealed a lack of published information on the subject. Because of this shortage of information from other sources, the techniques described here are presented in detail and, for the most part, they represent the methods used to install the cables for this project.

7.1.8.a Where cables are to be installed in vertical locations, the cable should be installed so that it is worked downward through the vertical run.

7.1.8.b Cable which is supplied on a reel should be removed by rotating the horizontally oriented reel while paying out the cable. Cable should not be removed from the reel by pulling it over the end of the reel. It may be necessary to station someone at the reel to assist with paying out the cable and to provide braking of the reel so that the cable does not run off when the pulling is stopped.



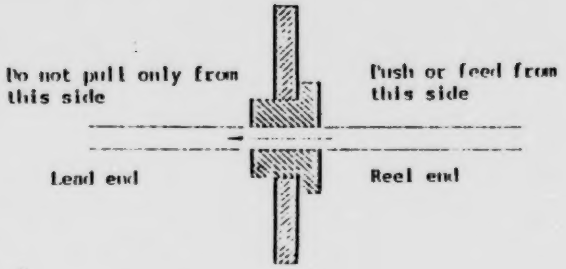
Correct Method

Incorrect Method

Figure 7.1.1

Cable Unspooling

7.1.8.c The cable or pulling rope should be guided or fed through any restrictions such as terminal tubes, kickpipes, etc., rather than pulled from the other side.



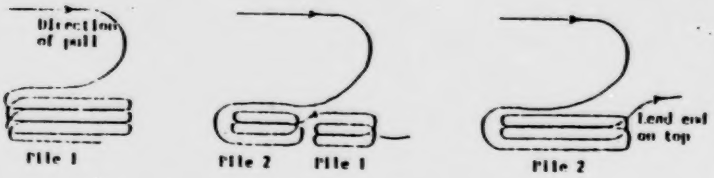
Cable Installation Through Restrictions

Figure 7.1.2

7.1.8.d When terminal tubes, stuffing tubes, etc. are fitted in place prior to the cable installation, these devices should be fitted with any retaining nuts, washers or circular packing material which cannot be added after the cable is installed. These items can be removed from the tube and worked along the cable as it is installed.

7.1.8.e For intermediate pulls, care should be taken not to pull an excessive amount of cable so that it becomes unmanageable. At intermediate pull locations, allow the cable to fall as it may or arrange it in a figure of 8, taking care not to allow the cable to be bent at less than the recommended bend radius. Do not attempt to recoil the cable.

7.1.8.f After completing an intermediate pull at the lead end of the cable, the lead end is located at the bottom of the pile. The pile should then be inverted by feeding the top of the pile into a second pile, eventually leaving the lead end at the top of the second pile.



Cable Management

Figure 7.1.3

This method may result in some minor tangles in the cable, but, provided that not too much cable is pulled at one time, these tangles should be easy to resolve. This method is also recommended for intermediate pulls which do not involve the lead end of the cable.

It is not advisable to invert the pile by picking it up and turning it over.

7.1.8.g When running the lead end of the cable or the pull rope, it must follow the cable route exactly. That is, the cable should be run around all obstacles as required.

7.1.8.h After the lead end of the cable is brought to the destination point, allow sufficient excess at the destination point for termination, etc and then start working the slack back towards the source end of the cable, securing the cable as the slack is worked out. In this manner, extra cable can be respooled or payed out as required.

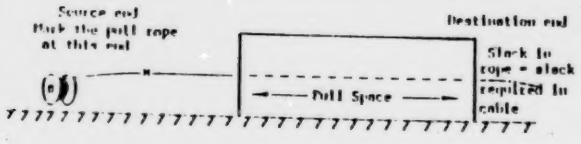
7.1.8.i Loosely fitted, plastic cable ties can be used to form a temporary guide for the cable as it is pulled into position along both vertical and horizontal runs.

7.1.8.j Difficulties may arise and caution is advised if trying to install more than one cable simultaneously.

7.1.8.k For areas where a pull rope is required to complete a cable run, the following technique is recommended.

(i) Using a fish, run the pull rope along the cable route, taking care to follow the route exactly.

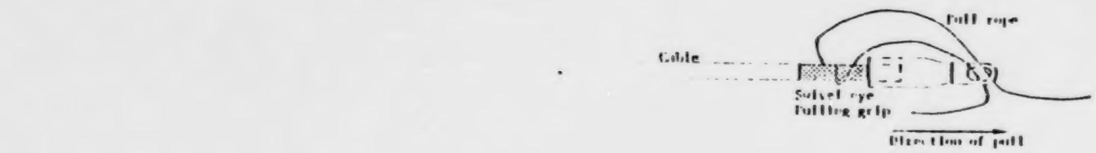
(ii) When the lead end of the pull rope is available at the destination end, mark the rope where it enters the run at the source end. By continuing to pull the rope through the run until the mark arrives at the destination end, the exact length of the run can be determined.


Source end
Mark the pull rope
at this end
Destination end
Slack in
rope = slack
required in
cable
Pull Space

Pull Rope Installation

Figure 7.1.4

(iii) When pulling cable with a pull rope, where space permits, it is suggested that the rope be installed along the cable route and that the cable be attached to a midpoint in the rope. This method minimizes the strain on the cable and allows for the cable to be backed out if it should become blocked. The method for fixing the rope to the cable is shown in figure 7.1.5.



Pulling Grip Attachment to Pull Rope

Figure 7.1.5

By attaching the cable to a midpoint of the pull rope, the pull rope remains in the pull space after the cable has been pulled into place. This allows for additional cables to be installed without reinstalling the pull rope.

(iv) The swivel eye pulling grip should have a recess in the head to accept the end of the cable. In this way the end of the cable is protected during the pull. To further protect the fibre cable from twisting, the pull rope should be of torque-balanced construction.

7.1.8.1 Wherever possible, cable installation should be started from one of the termination points rather than some intermediate point. This allows the cable to remain on the reel until the exact length has been determined thus minimizing cable wastage.

7.1.8.m At no time prior to, during, or following installation should optical cable be stored by hanging on hooks, pegs or dowels. When possible the cable should be stored on the original reel. When this is not possible it should be coiled or faked out on the deck, out of harm's way. Cable should be stored only on reels designed for use with fibre optic cable. The cable reel drum diameter should be not less than twice the minimum bend radius of the cable.

7.1.8.n During installation, as well as during transportation and storage, except when necessary to do otherwise, the ends of the cable should be sealed against moisture absorption and dirt. The preferred method for sealing cable ends is with adhesive filled or double-wall, meltable heat shrinkable caps. Alternatively, heat shrink tubing and end caps can be used.

When ordering cable it is sensible to specify that both ends of the cable be accessible on the shipping reel for inspection.

7.1.8.o When handling cables, both before and during installation, avoid abrading, crushing, twisting, kinking or pulling around sharp edges. Twisting or kinking is most likely to occur when a cable is removed from a reel or unwound from a coil.

7.1.8.p Cables should be formed in a sweep bend in which the bend radius is not less than the minimum bend radius of the cable. Bends at terminal entrances, where stuffing tubes are required, should be made via angle stuffing tubes.

Straight stuffing tubes may be used in place of angle stuffing tubes if the bend in the cable is not less than the minimum bend radius specified for that cable. Care should be taken while pulling the cable into wireways to avoid momentary sharp bends.

7.1.8.q During the pulling of the cable, a direct communication link should be maintained between all persons engaged in the operation.

7.1.8.r Avoid subjecting the cable to long term static stress.

7.1.8.s Bends which will be incurred during pulling of the cable should occur early, then mostly straight pulling afterwards. This will allow for a lower net pull force on the cable.

7.1.9 Cleanliness

Cleanliness must be maintained at all times when dealing with optical components. Connector faces should be cleaned with a suitable cleaning agent, such as isopropyl alcohol. Receptacles and bushings should be checked for cleanliness prior to attaching connectors; clean, dry, low pressure air, a cleaning agent which leaves no residue and clean, lint free cleaning swabs and tissues are recommended for cleaning purposes. The optimum time for cleaning optical connectoring components is just prior to connecting, be it to other components within the system or to test and measurement instruments. Receptacles and connectors should be fitted with dust caps when not in use.

The cleaning fluid used should be compatible with the materials used to construct the connector, including the seals, and also with the epoxy used to assemble the connector. Although no problems were observed with the connectors, it was observed that Tra-Con epoxy F113-SC is soluable in acetone, even after the epoxy is fully cured.

7.2 Subcable Design

The installation process highlighted the requirement for breakout boots and subcable assembly at the terminal equipment. In the case of this installation, the light duty (Siecor) cable was adequately constructed so that the subcabling (containing an individual fibre) could be terminated at the SMA connectors and splice enclosures. The heavy duty (Whitmor) cable did not have a construction that was suitable for SMA termination. The tubing fitted in this cable was replaced with the subcable jacketing material from the Siecor cable and heat shrink tubing was used to secure the new tubing in place as well as to form the breakout boots.

8.0 STANDARDS

8.1 Sources of Information

The primary objective of this project was to develop a set of draft standards which would assist designers, ship builders and operators in the implementation of fibre optic systems onboard ships. In the process of drafting these standards, similar documents from a number of different agencies were obtained. These included:

- Electronic Industries Association (EIA)
- International Electrotechnical Commission (IEC)
- United States of America, Department of Defense (DOD)
- United States of America, National Aeronautics and Space Administration (NASA)
- American National Standards Institute (ANSI)
- Institute of Electrical and Electronic Engineers (IEEE)
- Canadian Standards Association (CSA)
- Society of Naval Architects and Marine Engineers (SNAME) - newly formed
- Transport Canada (TC)
- Japan Radio Corporation (JRC)

In addition, information for the proposed standards was obtained from the pilot installation onboard the Canadian Coast Guard ship Louis S.St. Laurent and from the general knowledge and experience of Focal Marine Limited (FML).

8.2 Draft Standards

Those aspects of fibre optics which have particular requirements for shipboard applications have been addressed in the draft standards. These standards, which make up Volume II of this report, cover the following topics:

- optical fibre
- optical fibre cable
- optical fibre cable installation
- optical transmitters and receivers
- optical couplers including multiplexers and switches
- optical fibre connectors
- optical fibre splices
- enclosures for use with optical fibres and optical fibre cables and components
- equipment for use with optical systems.

In drafting the standards, maximum use was made of existing documents, i.e. non-shipboard fibre optic standards and non-fibre optic shipboard standards.

9.0 GENERAL CONCLUSIONS

It may be generally concluded that fibre optic technology is ready for shipboard application. The shortcomings identified in the pilot system resulted from design features implemented deliberately in order to highlight areas of sensitivity or weakness, always with the preparation of standards in mind.

9.1 Cable

The cables were exposed to the shipboard environment for approximately 14 months from the beginning to the end of the test period. Over the short term, there was no appreciable degradation of either the light duty of the heavy duty cables. This is not unusual because, it has been found, that "for low phosphorous doped multimode fibre (less than 1% by weight), up to approximately 0.06 dB/km at 1300 nm can be expected after 30 years." [2] At this rate of loss, one year of exposure can be considered a very short term, producing insignificant increases in cable losses.

There was a concern that hydroxyl ions or hydrogen attach would lead to microcrack propagation or attenuation increase. However neither cable showed serious deterioration, so that it cannot be concluded that water blocking (gel filling) is a requirement for shipboard optical cables without much longer-term tests.

External braid is not considered to be essential for shipboard fibre cables.

9.2 Vibration, Temperature, EMI

Analysis of the logged data has shown no correlation between optical power and the ambient temperature and vibration or with the presence of a large amount of EMI. Provided that sufficient flux margin is maintained, so that the receivers are not operated near the limit of their sensitivity, a good BER should be achievable in the normally encountered temperature, vibration and EMI of a shipboard environment.

9.3 Cooling of Optical Transmitters

The material given in section 6.6.3, 'Source Power Measurements' identified decreases in the output power of the sources between the start and the end of the test period. A certain reduction in output power with time is normal for LED operation. The lifetime of a LED is the time it takes for the power to reduce to half of its initial value. For a good LED, when operated with the specified limits of power, voltage, current and temperature, a lifetime of 10^8 hours is common.[3]

At elevated temperatures, the output power decreases by approximately 1% per degree Celsius. An increase in the junction temperature of 50 degrees Celsius can result in a 3 dB decrease in output power and a significant decrease in the lifetime of the device.[4]

Hence cooling of optical transmitters should be considered in shipboard applications, as in any good design. This may imply ventilated cabinets if space is restricted, allowing adequate space for convective cooling within the enclosure, or active cooling (such as a thermo-electric device) in more severe cases such as boiler room installations. Such extreme locations can normally be avoided.

9.4 Receivers

Due consideration must be given to receiver dynamic range. In addition to the BER problems of receivers operated near the lower limit of sensitivity, as described in section 6.5.1, detectors operated at the low limit of their sensitivity necessitate the use of high gain amplifiers at the front end of receiver circuits. This configuration should be avoided due to the intrinsic noise problems associated with high gain front end amplifiers.

Maintaining the temperature of the detector and front end amplifier circuits within specified limits is necessry to limit the effects of thermal noise. Where the ambient temperature may be high, as in the case for many areas of a ship, some means of temperature regulation may be required, as outlined in the foregoing section.

9.5 Choice of Wavelengths

Long wavelength LED's (1300 nm and above) are usually much more expensive than shorter wavelength LED's in the 850 nm range. Although signal attenuation at longer wavelengths is usually lower in fibre than it is at shorter wavelengths, the fibre induced attenuation of short haul, shipboard systems is not usually critical in terms of the overall budget. In addition, it is more difficult to launch light from a long wavelength source into a fibre. The result of this is often the added inconvenience of having to deal with a pigtailed source as well as having less light coupled into the fibre. Reduced coupled power offsets the lower rate of attenuation associated with the longer wavelength source. For these reasons, short wavelength sources are recommended over long wavelength sources.

9.6 Two Wavelength Operation

Although current technology allows for operation of a fibre optic system, using LED sources, at two wavelengths, doing so forces one to cope with the problems associated with long wavelength operation as described in section 10.5. Before committing to two wavelength operation, consideration to running two short wavelength systems in parallel should be given.

For two-channel digital systems, two short wavelengths may be acceptable (perhaps 100 nm apart) on a single fibre, because the crosstalk performance is not as demanding as with analog (video) operation. This would avoid the problems of the long wavelength devices while giving economy in cable length and weight.

9.7 Pigtails

Besides the normal considerations given to fibre optic components and devices for use onboard ships, additional considerations are necessary when specifying pigtailed components or devices. The pigtails must be suitably bonded or otherwise secured to the component or device so as to remain so attached during all working and storage conditions. Pigtails should be sufficiently long as to allow for proper connectoring or splicing of the free end while still maintaining a sufficient length to allow for proper storage when in use, access to the equipment and/or splices as required, retermination or resplicing a specified number of times, and to ensure that no less than the minimum bend radius is maintained during all of the above mentioned conditions. A one-meter minimum length is a useful guide. The material used for the pigtail jacket construction should be suitable for shipboard use in terms of providing adequate, long term protection to the fibre and low flammability. The pigtail construction should be suitably matched with the intended method of termination.

9.8 Splices

Splices used with optical fibre, whether of the mechanical type or the fusion type, should be provided with adequate protection and strain relief. Where a multitude of splices are to be accommodated in a single enclosure, the cable or cables entering the enclosure should be strain relieved, in addition to the strain relief provided adjacent to and at each end of the splice. The splice protection device should be suitably supported so as not to put undue stress on the splice or the cable. Only in splices of the type designed for freestanding applications should the splice be entirely supported by the cabling. Particular attention should be paid to the risk of strain induced end separation in the case of mechanical splices. Reenterable splices are more risky in this respect than those which are permanently sealed.

9.9 Encoding

Some form of encoding format is necessary for a digital, fibre optic link. The use of a given format for data coding invariably is done at the expense of some application feature, such as transmission speed, stability of clock regeneration, ease of data detection, data throughput rate, phase synchronization, error checking and/or complexity of implementation.

It is for the system designer to decide what features are important and which ones can be compromised for a particular system. Two-level pulse code formats are ideally suited for fibre optic systems as they exist today. As the field continues to develop, multilevel code formats may become practicable for shipboard applications.[5]

10.0 RECOMMENDATIONS

10.1 Standards

The main recommendation is that the draft Proposed Standards be put to maximum use, in order to encourage and facilitate the use of fibre optics onboard Canadian vessels. This can be achieved through several actions:

- review of the drafts by Coast Guard staff, Canadian Steamship Inspectors and possibly other groups
- presentation of the drafts (modified by Coast Guard staff as necessary) to existing standards committees, to influence the publications of such committees
- initiation of a new project to keep the standards up to date as the technology develops and as other standards agencies issue new documents. This would include interaction with the Japanese, EIA, IEC, SNAME and others
- revisiting the Louis S.St. Laurent on an annual or semi-annual basis to monitor cable losses and other system performance parameters, to develop long-term performance data.

10.2 Shipboard Configuration

Another recommendation is that the fibre system on the CCGS Louis S.St. Laurent be put to best advantage. It currently has a functioning video system, but there is no equipment on that vessel to utilize the IEEE-488 digital channel (this was conceived with the Polar 8 in mind). The digital channel could be converted to a second video channel to utilize the available fibre capacity; alternatively, or additionally, sensor data could be supported on the fibre medium. Any such plans should bear in mind the scheduled refit of the Louis S.St. Laurent, to include a power conversion; some areas such as the main propulsion motors will not be affected but other areas will be torn down.

It is recommended that there be a concentration on low-rate sensor buses using fibre as the medium. This would complement work on DND projects where high-rate digital signals and high bandwidth sensors are to be interfaced to fibre optic buses. A commonly encountered problem on ships is to find an affordable means of acquiring signals from several dozen such low-rate sensors clustered in one area of the ship, and combine the signals for use and display both locally and remotely. The existing fibre cables can serve to deliver the signals to the remote locations; the conentration should therefore be on the interfaces and sensor standardization required to get the signals to the node efficiently. Once achieved, such a system would be beneficial, being immune to EMI, relatively corrosion resistant, rugged and expandable.

Any such system would have to cater at least initially to both conventional electrical sensors and fibre optic sensors. Outputs of fibre optic sensors would utilize methods, such as spectral shifts, that are not prone to errors caused by line loss variation.

11.0 REFERENCES

1. Robert M. Morais, Implementation of Fibre Optic Technology in Naval Combatants, Marine Technology, Volume 24, No. 1, January 1987, pp 59-71.

2. Otto I. Szentesi, Reliability of Optical Fibres, Cables, and Splices, IEEE Journal On Selected Areas in Communications, Volume SAC-4, No. 9, December 1986, pp 1502-1508.

3. Joseph C. Palais, Fibre Optic Communications, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1984, pg 127.

4. Henry Kressel, J.K. Butler, Semiconductor Lasers and Heterojunction LEDs, Academic Press Inc., New York, 1977, pg. 552.

5. David J. Morris, Pulse Code Formats For Fibre Optic Data Communication, Marcel Dekker Inc., New York, N.Y, 1983, pg. v.

Appendix A

TEST RESULTS

Page

Heavy Duty Fibre Optic Cable Acceptance Test Results A-2

Light Duty Fibre Optic Cable Acceptance Test Results A-7

Cable Bend Radius Test A-13

Cable Compressive Loading Test . A-14

Transmissive Star Coupler Acceptance Test Results A-15

Optical Assembly Test Results A-22

Video Fibre Optic Transmission System Test Results A-28

Scientific Data Highway (SDH) Acceptance Test Report A-30

Digital Transmitter Test Results A-36

Heavy Duty Fibre Optic Cable Acceptance Test Results

Ref. Dwg. No.:	3-8468-201-0
Date:	August 15, 1985
Manufacturer:	Whitmor Waveguides
Part Number:	2-123-12-6/4-100

Visual Inspection

The cable appeared to be undamaged and to conform to the specified configuration in terms of component types, component arrangement and dimensions.

Optical Inspection

The length, as determined by the OTDR, was within the specified length plus tolerance.

The attenuation of the fibres within the cable could not be measured accurately because the cable was coiled on a shipping/storage reel. Reeled cable exhibits higher attenuation per unit length than straight cable.

Attenuation measurements with the cable on the reel indicated an attenuation of approximately 2dB for the 307m length, on each fibres.

This result confirmed a specific attenuation within 6dB/km as specified by the manufacturer.

WHITMOR WAVEGUIDES

A DIVISION OF WHITMOR WIRE & CABLE CORPORATION

WHITMOR WAVEGUIDES QUICK-QUOTE

1.0 QUOTE NUMBER: 85-26 Rev 13

2.0 CUSTOMER: Focal Marine

3.0 CONTACT: Mike Jerrett

4.0 QUANTITY: 300m

LENGTHS: 1× 300m

TOLERANCE: ☒ -0,+10% ☐ ________

5.0 FIBER SPECIFICATIONS

NUMBER OF FIBERS: 2

CORE/CLAD DIAMETERS (MICRONS): 100 / 140 (NOMINAL)

PROFILE: ☐ STEP ☐ SEMI-GRADED ☒ GRADED

CORE/CLAD MATERIALS: ☒ GLASS/GLASS ☐ GLASS/HARD PLASTIC ☐ GLASS/SILICONE ☐ PLASTIC/PLASTIC

6.0 OPTICAL SPECIFICATIONS

ATTENUATION: 6 db/km at 850 nm; 4 db/km at 1300 nm

BANDWIDTH: 100 MHZ-KM at 850 nm; 100 MHZ-KM at 1300 nm

— psec/nm km at — nm

NUMERICAL APERTURE (5% VALUE): 0.2 (MINIMUM)

7.0 CABLE SPECIFICATIONS

BUFFER TUBE/CABLE DIAMETERS(INCHES): .080 2.0 mm / 0.459 11.66 mm

MAXIMUM INSTALLATION/MAXIMUM USE FORCE (POUNDS): 225 511 kg / 45 91 kg

TEMPERATURE RANGE OF USE (°C): -40+50 ; CRUSH STRENGTH (POUNDS/INCH): NS

MINIMUM BEND RADIUS (INCHES): 4.84 12.2 cm

JACKET MATERIAL: POLYURETHANE+BRAID JACKET COLOR: BLACK

PRINTING: - NONE

FLAME RESISTANCE OF CABLE: ☐ NONE ☑ VW-1

6/29/84
PAGE 1 of 2

13161 SHERMAN WAY • NORTH HOLLYWOOD, CA 91605 • (213) 764-6298 • (213) 875-0011 • (213) 983-1

WHITMOR
WAVEGUIDES
A DIVISION OF WHITMOR WIRE & CABLE CORPORATION

COLOR-CODING OF FIBERS: ☒ NONE ☐ RAISED RIB ☐ KEYED
☐ INDIVIDUALLY COLOR-CODED FIBERS

STRUCTURE: ☒ CONCENTRIC ☐ ZIP-CORD DUPLEX ☐ OVAL-DUPLEX

.0 SUGGESTED APPLICATION

☒ INDOORS, TRAYS, DUCTS, CONDUITS
☒ RODENT-RESISTANT
☒ WATER BLOCKED OR FILLED
☒ OUTDOORS
☐ DIRECT BURIAL
☐ ALL-DIELECTRIC/HIGH VOLTAGE USE
☒ HIGHLY-FLEXIBLE DESIGN
☐ RADIATION-RESISTANT DESIGN
☐ LASHED AERIAL
☐ SELF-SUPPORT AERIAL
☐ PLENUM

.0 CONNECTORS ☒ NONE
☐ TYPE:

.0 TERMS
NET 30, 1% NET 10 ON APPROVED CREDIT
F.O.B. ☒ N. HOLLYWOOD, CA ☐

.0 DELIVERY: 3-5 WEEKS ARO'

.0 PART-NUMBER: 2-123-12-6/4-100

.0 PRICE: 7.99 /m

QUOTE GOOD FOR 30 DAYS FROM 5/1/85

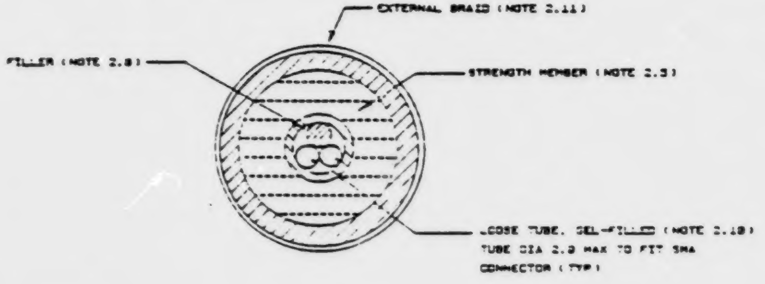
.0 APPROVED: , VICE PRESIDENT

.0 NOTES: 1. NO ADDITIONAL SPECIFICATIONS ARE PRESENTED ON ATTACHED SHEET(s)
2. THIS DOCUMENT CONTAINS THE ENTIRE SPECIFICATION FOR THIS PRODUCT
3. N.S. MEANS NOT SPECIFIED

6/29/84

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED


EXTERNAL BRAID (NOTE 2.11)
FILLER (NOTE 2.8)
STRENGTH MEMBER (NOTE 2.5)
LOOSE TUBE, GEL-FILLED (NOTE 2.10)
TUBE DIA 2.0 MAX TO FIT SMA
CONNECTOR (TYP)

1.0 FIBRE SPECIFICATIONS

1.1 FIBRE SIZE (CORE/CLAD): 100/140 µm ± 2
1.2 TYPE: GRADED INDEX
1.3 NUMERICAL APER TURE >0.2
1.4 ATTENUATION: < 5 dB/km @ 850 nm
< 3 dB/km @ 1300 nm
1.5 BANDWIDTH: >100 MHz km
1.6 BUFFER: MATERIAL SILICONE OR EQUIVALENT
DIAMETER 300 µm MAXIMUM

2.0 CABLE SPECIFICATIONS

2.1 NUMBER OF FIBRES: 2 OR 3 (TWO TO BE CERTIFIED PER NOTE 3.0 AND IDENTIFIABLE BY COLOUR OF BUFFER)
2.2 TENSILE LOADING (WITH NO DEGRADATION OF FIBRE PROPERTIES): 1000 N (INSTALLATION)
200 N (OPERATING)
2.3 OUTER DIAMETER (OD): MAX 13 mm
2.4 MINIMUM BEND RADIUS : MAX 10 TIMES O.D.
2.5 STRENGTH MEMBER: KEVLAR ARAMID FIBRE.
2.6 WEIGHT <0.20 kg/m (SPECIFY)
2.7 OUTER JACKET FLAME RETARDANT, UV RESISTANT PVC OR POLYURETHANE TO MEET IEEE STANDARD 45.
2.8 CONSTRUCTION: 3 BUFFERED FIBRES (OR 2 FIBRES AND NON-HYGROSCOPIC FILLER) WOUND IN HELIX (SPECIFY PITCH). CENTRAL FILLER FOR WINDING ACCEPTABLE. INNER JACKET (SPECIFY MATERIAL). STRENGTH MEMBER. OUTER JACKET. FILLERS (NON-HYGROSCOPIC) ACCEPTABLE IN INTERSTICES. OUTER PROFILE IS TO BE SUBSTANTIALLY CIRCULAR.
2.9 EXCESS ATTENUATION DUE TO CABLING: < 1 dB/km
2.10 MOISTURE BLOCK: GEL-FILLED LOOSE TUBE AS SHOWN. SPECIFY GEL MATERIAL (NON-HYGROSCOPIC)
NOTE: ALTERNATIVE MOISTURE BLOCK TO GEL IS WELDED OR EXTRUDED METAL TUBE AROUND EACH FIBRE BUFFER OR CERAMIC COATING ON FIBRE; IN THIS CONFIGURATION LOOSE TUBE BUFFER IS NOT ESSENTIAL. SPECIFY MATERIAL.
2.11 BRAID: ALUMINUM, STAINLESS STEEL OR BRONZE (SPECIFY) THAT MEETS IEC 92-3 REQUIREMENTS.

3.0 CERTIFICATION

3.1 FIBRE: ALL FIBRE PROPERTIES SPECIFIED IN SECTION 1.0 TO BE CERTIFIED BY FIBRE SUPPLIER. COPY OF CERTIFICATION TO BE PROVIDED.
3.2 CABLE: ALL OTHER REQUIREMENTS OF THIS DRAWING TO BE CERTIFIED BY CABLE SUPPLIER.

MATERIAL —
FINISH —

UNLESS OTHERWISE NOTED:
ALL DIMS IN MILLIMETERS
1 DEC PLACES ±0.25
2 DEC PLACES ±0.08
ANGLES ±
ECCENTRICITY
SURFACE ROUGHNESS
REMOVE SHARP EDGES

CONTRACT NO
DRAWN
CHECKED
APPROVED
DATE 28 MAR 85

FOCAL MARINE LIMITED
BEDFORD HIGHWAY
BEDFORD NOVA SCOTIA

TITLE CABLE, FIBREOPTIC, [illegible]

SIZE | DRAWING NO
B 3-3468-201-0

SCALE | SHEET | OF

NEXT ASSY | USED ON
APPLICATION

REVISIONS			
ZONE LTR	DESCRIPTION	DATE	APPR

4.0 ENVIRONMENTAL CONDITIONS

4.1 OPERATING TEMPERATURE: [illegible] DEGREES TO [illegible] DEGREES C
WITH NO MORE THAN 2.0 dB ATTENUATION CHANGE
RELATIVE TO ATTENUATION AT 20 DEGREES C.

4.2 STORAGE TEMPERATURE: -30 DEGREES C TO +30 DEGREES C
WITH NO CHANGE IN ANY FIBRE OR CABLE PROPERTIES
AFTER RETURN TO 20 DEGREES C.

5.0 SHIPPING CONFIGURATION

5.1 DRUM DIAMETER: >30 cm

5.2 CABLE ENDS: TO BE PROTECTED AGAINST MOISTURE
PENETRATIONS OR MECHANICAL DAMAGE, AS APPROPRIATE;
BOTH ENDS ACCESSIBLE FOR TESTING.

5.3 LENGTHS: THE LENGTH OF CABLE ON THE DRUM SHALL BE
NOT LESS THAN 300 m UNLESS ORDERED IN SHORTER
LENGTHS IN WHICH CASE IT SHALL BE IN THE
LENGTH SPECIFIED. TOLERANCE ON LENGTH - 0 + 10%

6.0 ACCEPTANCE TEST REQUIREMENTS

6.1 VISUAL INSPECTION: EXAMINE CABLE FOR GENERAL
CONFORMANCE TO REQUIREMENTS. NOTE ANY SIGNS OF
DAMAGE, BLEMISHES ETC. RECORD OBSERVATIONS.

6.2 ATTENUATION: MEASURE AND RECORD THE ATTENUATION
AT EACH WAVELENGTH WHILE THE CABLE IS STILL ON
THE SHIPPING DRUM, USING THE HP8151A OR PHOTODYNE
22XLA POWER METER.
THE MEASURED ATTENUATION SHALL NOT BE MORE THAN
1 dB/km IN EXCESS OF THE MAXIMUM SPECIFIED
ATTENUATION (SEE NOTES 1.4 AND 2.3)

MATERIAL

FINISH

UNLESS OTHERWISE NOTED:
ALL DIMS IN MILLIMETERS
2 DEC PLACES ±0.25
1 DEC PLACES ±0.50
ANGLES ±
ECCENTRICITY [illegible] MAX
SURFACE ROUGHNESS
[illegible] MAX
REMOVE SHARP EDGES
[illegible] MAX

NEXT ASSY | USED ON
APPLICATION

CONTRACT NO

DRAWN

CHECKED

APPROVED

DATE
28 MAR 85

FOCAL MARINE LIMITED
[illegible] BEDFORD HIGHWAY
BEDFORD NOVA SCOTIA [illegible]

TITLE
CABLE, FIBREOPTIC,
[illegible]

SIZE DRAWING NO
B 3-8468-201-0

SCALE [illegible] SHEET [illegible] OF [illegible]

Light Duty Fibre Optic Cable Acceptance Test Results

Ref. Dwg. No. 3-8468-202-0
Date: July 19, 1985
Manufacturer: Siecor Corp.
Part Number: 00244-PO27001

Visual Inspection

The cable appeared to be undamaged and to conform to the specific configuration in terms of component types, component arrangement and dimensions.

Optical Inspection

The length, as determined by OTDR, was within the specified length plus tolerance.

The attenuation of the fibres within the cable could not be measured accurately because the cable was coiled on a shipping/storage reel. Reeled cable exhibits higher attenuation per unit length than straight cable.

Attenuation measurements with the cable on the reel indicated an attenuation of approximately 1.25 dB for the 301 meter length, on each fibres.

This result confirmed a specific attenuation within 7dB per kilometer as specified by the manufacturer.

Siecor Specifications and Part Numbers

Optical Specifications

No. of Fibers	Unit of Measure	Optical Data	Light Duty Cables 1 Fiber	Light Duty Cables 2 Fiber	Heavy Duty Fan Out™ Cables 2 Fiber	Heavy Duty Fan Out™ Cables 4 Fiber	Heavy Duty Fan Out™ Cables 6 Fiber	Heavy Duty Fan Out™ Cables 8 Fiber
Max. attenuation @ 850 nm	dB/km	7.0	00144-007001	00244-007001	00244-P027001	004441P007001	006441P007001	008441P007001
Max. attenuation @ 1300 nm	dB/km	6.0						
Min. bandwidth @ 850 & 1300 nm (3 dB optical)	MHz-km	100						
Numerical aperture, nominal		0.29						
Core diameter	µm	100						
Cladding diameter	µm	140						
Buffering diameter	µm	900						
Max. attenuation @ 850 nm	dB/km	7.0	00144-007003	00244-007003	00244-P027003	004441P007003	006441P007003	008441P007003
Max. attenuation @ 1300 nm	dB/km	6.0						
Min. bandwidth @ 850 & 1300 nm (3 dB optical)	MHz-km	300						
Numerical aperture, nominal		0.29						
Core diameter	µm	100						
Cladding diameter	µm	140						
Buffering diameter	µm	900						
Max. attenuation @ 850 nm	dB/km	7.0	00104-007004	00204-007004	00204-P027004	004041P007004	006041P007004	008041P007004
Max. attenuation @ 1300 nm	dB/km	6.0						
Min. bandwidth @ 850 & 1300 nm (3 dB optical)	dB/km	400						
Numerical aperture, nominal		0.2						
Core diameter	µm	50						
Cladding diameter	µm	125						
Buffering diameter	µm	900						

Mechanical Specifications*

			Light Duty Cables 1 Fiber	Light Duty Cables 2 Fiber	Heavy Duty Fan Out™ Cables 2 Fiber	Heavy Duty Fan Out™ Cables 4 Fiber	Heavy Duty Fan Out™ Cables 6 Fiber	Heavy Duty Fan Out™ Cables 8 Fiber
Storage temperature range, on original shipping reel	C		-40° to +70°		-40° to +70°			
Operating temperature range, installed*	C		-20° to +70°		0° to +70°**	-20° to +70°		
Max. tensile load for installation	N		300	600*	1,000			
Max. tensile load, long term installation	N		50	100*	150			
Min. bend radius for installation	cm		5	5*	15	22	26	30
Min. bend radius, unloaded (free) installation	cm		3	3*	7.5	11	13	15
Crush resistance, long term installation	N/cm		550		700			
Max. vertical rise**	m		300		150	70	50	40
Impact Resistance (min value for fiber breakage, 12.5mm hammer radius)	times N/cm		20 1		50 3			
Flexing, ± 90° (no damage)	times		10,000		1,000			
Cable outside diameter, nominal	mm		3.0	3.0 × 6.0	9.0	11	13	15
Cable weight, nominal	kg/km		7.5	15	80	110	145	185

Shipping Information*

Reel size	F cm T cm D cm		15 10 10	15 10 20	32 18 22	32 18 22	35 30** 23	35 30** 23
Reel weight	kg		3	3	50*	50*	77*	77*

Equally loaded
Horizontal axis
All tests are performed in accordance with all industry testing standards
Isolated exposure of short lengths of cable (e.g. inside electronic equipment to temperatures as high as 85° C) will not significantly degrade the overall system performance
Standard shipping lengths 1 kilometer
Additional requirements for [illegible] compliance and for UL listing of cable to be used in vertical runs are under consideration
Intermediate tie-downs required for security
Lagged weight, excludes cable weight
For interfacing connection of [illegible] equipment. See Note 4

Siecor Series 4 optical cables are specifically designed for data, voice and image transmission in computer, process control, data entry and wired office systems. These cables are optimized for either short distance applications or in building distribution as part of long distance, high performance optical cable transmission systems. The Series 4 cables are available in configurations of 1, 2, 4, 6, or 8 fibers. These cable constructions allow easy connectorization, either before installation or on site, using single fiber connectors available from over 15 manufacturers.

Characteristics

All Series 4 cables provide:

- Electrical isolation
- Immunity to EMI
- Elimination of ground loop problems
- Wavelength division multiplexing capability in the 850 and 1300 nm regions

All Series 4 cables have:

- Flame retardant sheaths to meet safety standards (sheaths pass Underwriters Laboratories' VW1 vertical flame test)
- Easily strippable jacket(s) and fiber buffer(s)
- Flexible, rugged constructions allowing easy installation
- Mechanical stability and performance characteristics inherent in all glass fibers
- Resistance to chemicals, humidity and water

Construction

Siecor Series 4 cables use a modular concept based on Siecor's single fiber cable. The single fiber cable construction consists of a fiber, protected by a 900 micrometer (µm) tight buffer which is mechanically strippable. High strength aramid yarns are stranded around the buffered fiber. An orange flame resistant sheath completes this cable or subunit construction.

There are two options available for the 2 fiber cable construction. The light duty 2 fiber cable is simply two modular subunits joined together. This "lampcord" style cable is easily separated for individual termination of each fiber. The heavy duty 2 fiber cable consists of two subunits stranded with aramid yarns to form the cable core which is then jacketed with black flame retardant polyvinylchloride (PVC).

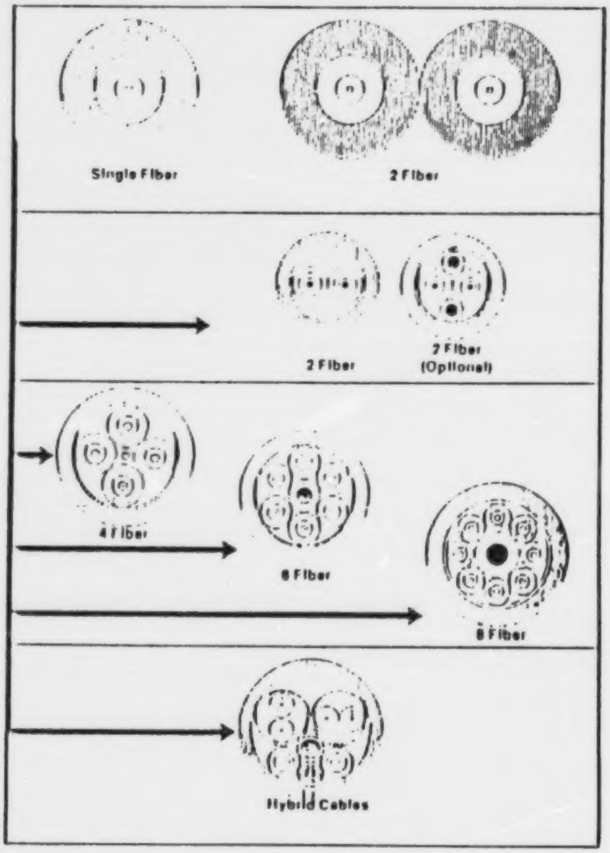
The Series 4 Fan-Out™ cables are heavy duty cable designs containing four, six, or eight single fiber cable subunits. The subunits are stranded around an all dielectric structural element to form the cable core. The core is then surrounded by a layer of stranded aramid yarns and jacketed with black flame retardant PVC. A lower cost metallic structural element is available as an option. A rip cord is also incorporated into each Fan-Out cable for easy jacket removal. Each cable jacket is identified as "Siecor Optical Cable" and sequentially meter marked. Each individual subunit is uniquely number identified approximately every 30 cm.

The modular concept is also used in custom cables, such as hybrid cables combining twisted wire pairs and power conductors with optical fibers.

Termination

The Siecor Series 4 cable jackets can be removed using simple cutting tools. Both the primary and secondary buffer can be easily stripped from the all glass fiber by mechanical stripping techniques, leaving a clean surface ready for connector installation. All materials, tools and instructions (Siecor Technical Bulletin #16) needed to prepare the fiber for splicing or connectorization are available in Siecor's TKT-005 stripping tool kit.

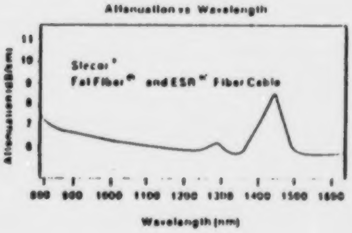
The concentric aramid yarn strength member facilitates anchoring to the connector shell using standard techniques. The non-deforming, all-glass fiber provides a constant, well-defined relationship between the outer surfaces of the cladding and the center of the core.



Optical Characteristics

Siecor cable can be used with a wide variety of source wavelengths from 800 nm to 1300 nm. The following cable characteristics reflect type data and are intended to aid the design engineer in applying Siecor Series 4 optical cables.

Attenuation vs Wavelength



Siecor Fat Fiber® Cables

The 100 μm core Fat Fiber cables are designed for reliable, high performance systems with 10 to 2000 meter link lengths, such as the private network applications in automated offices, control systems, utilities, campuses, computer equipment, and banks. The combination of 100 μm core and 0.29 numerical aperture (NA) improves LED input coupling by 6 to 8 dB over the 50 μm core fibers. With a core diameter twice as large as 50 μm core fibers, the Fat Fiber cable may also have lower losses for a given connector design, or potentially allow the use of lower cost connectors with equivalent performance.

The Fat Fiber Cable is specifically designed for use with low cost LED sources and PIN detectors. Additionally total system cost is reduced by avoiding thermoelectric coolers and high voltage power supplies which are commonly needed with optical data systems employing lasers and avalanche photodiodes.

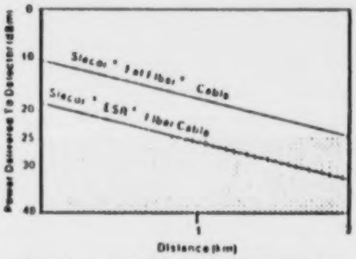
Siecor ESR® Fiber Cable

The 50 μm core Extended Spectral Response (ESR) cable products are the ideal intrabuilding interconnect cables for use in high data rate trunks. The fiber is directly compatible with proposed or existing optical cable standards (e.g., EIA, REA, IEC, CCITT).

The ability to upgrade transmission equipment from short to long wavelength or add wavelength multiplexers allows increased span length and bandwidth, extending useful system life. The ESR multimode fiber is suitable for operation over the range of infra red wavelengths from 800 to 1300 nm. For extremely high performance systems, custom cables can be ordered with other fiber types having bandwidths exceeding 1 GHz•km.

Link Design Considerations

The determination of practical link length depends on a number of factors. The factors for a non-bandwidth limited system include fiber diameter, fiber NA, cable attenuation, source output, receiver sensitivity, and connector losses. Shorter distance optical data links are typically designed with low cost LEDs and PINS. A sensitivity of -25 to -40 dBm, attainable in a low cost receiver using current technology, can be



Available power with Motorola MFOE 1202 LED in AMP Optimate™ Package, or Honeywell SE3352-004 LED (Fat Fiber), SE3362-005 LED (ESR Fiber) in Sweet Spot™ Package

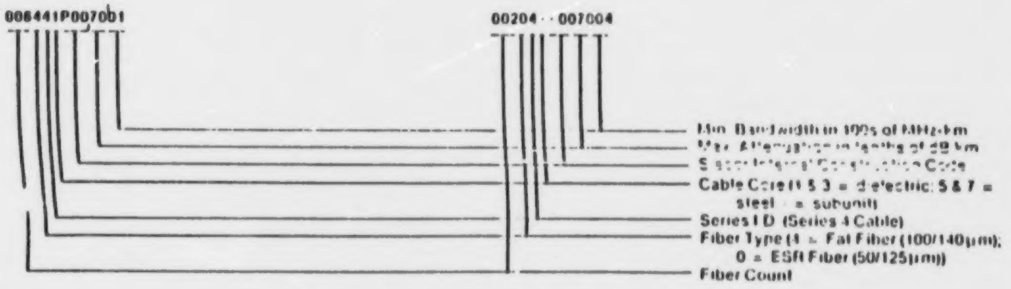
Product Code Description

6 Fiber Fan Out™ cable with 100 μm core/140 μm cladded fiber, dielectric cable core.

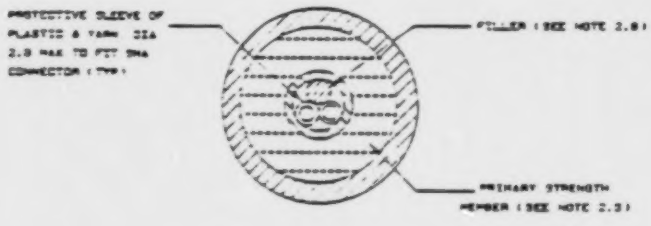
Max. Attenuation @850 nm: 7.0 dB/km
Max. Attenuation @1300 nm: 6.0 dB/km
Min. Bandwidth @850 and 1300 nm: 100 MHz•km

2 Fiber Light Duty cable with 50 μm core/125 μm cladded fiber "lampcord" construction.

Max. Attenuation @850 nm: 7.0 dB/km
Max. Attenuation @1300 nm: 6.0 dB/km
Min. Bandwidth @850 and 1300 nm: 400 MHz•km


006441P007001
00204··007004
Min. Bandwidth in 100s of MHz•km
Max. Attenuation in tenths of dB/km
Siecor Internal Construction Code
Cable Core (1 & 3 = dielectric; 5 & 7 = steel; - = subunit)
Series I.D. (Series 4 Cable)
Fiber Type (4 = Fat Fiber (100/140 μm); 0 = ESR Fiber (50/125 μm))
Fiber Count

REVISIONS			
ZONE	DESCRIPTION	DATE	APPR'D


PROTECTIVE SLEEVE OF PLASTIC & YARN DIA 2.0 MAX TO FIT SMA CONNECTOR (TYP)
FILLER (SEE NOTE 2.8)
PRIMARY STRENGTH MEMBER (SEE NOTE 2.3)

1.0 FIBRE SPECIFICATIONS

1.1 FIBRE SIZE (CORE/CLAD): 100/140 µm $^{+2}_{-}$
1.2 TYPE: GRADED INDEX
1.3 NUMERICAL APERTURE: > 0.2
1.4 ATTENUATION: < 5 dB/km @ 850 nm
< 3 dB/km @ 1300 nm
1.5 BANDWIDTH: >100 MHz km
1.6 BUFFER: MATERIAL SILICONE OR EQUIVALENT
500 µm MAXIMUM

2.0 CABLE SPECIFICATIONS

2.1 NUMBER OF FIBRES: 2 OR 3 (TWO TO BE CERTIFIED PER NOTE 2.8 AND IDENTIFIABLE BY COLOUR OF BUFFER)
2.2 TENSILE LOADING (WITH NO DEGRADATION OF FIBRE PROPERTIES): 1000 N (INSTALLATION)
200 N (OPERATING)
2.3 OUTER DIAMETER (OD): MAX 12 mm
2.4 MINIMUM BEND RADIUS: MAX 2 TIMES 2.3
2.5 STRENGTH MEMBER: KEVLAR ARAMID FIBRE
2.6 WEIGHT <0.15 kg/m (SPECIFY)
2.7 OUTER JACKET: FLAME RETARDANT, UV RESISTANT PVC OR POLYURETHANE TO MEET IEEE STANDARD 45.
2.8 CONSTRUCTION: 3 BUFFERED FIBRES (OR 2 FIBRES AND NON-HYGROSCOPIC FILLER) WOUND IN HELIX (SPECIFY PITCH). CENTRAL FILLER FOR WINDING ACCEPTABLE. INNER JACKET (SPECIFY MATERIAL). STRENGTH MEMBER; OUTER JACKET. FILLERS (NON-HYGROSCOPIC) ACCEPTABLE IN INTERSTICES. OUTER PROFILE IS TO BE SUBSTANTIALLY CIRCULATED.
2.9 EXCESS ATTENUATION DUE TO CABLING: < 1 dB/km

3.0 CERTIFICATION

3.1 FIBRE: ALL FIBRE PROPERTIES SPECIFIED IN SECTION 1.0 TO BE CERTIFIED BY FIBRE SUPPLIER. COPY OF CERTIFICATION TO BE PROVIDED.
3.2 CABLE: ALL OTHER REQUIREMENTS OF THIS DRAWING TO BE CERTIFIED BY CABLE SUPPLIER.

4.0 ENVIRONMENTAL CONDITIONS

4.1 OPERATING TEMPERATURE: 0. DEGREES C TO +35 DEGREES C WITH NO MORE THAN 0.2 dB ATTENUATION CHANGE RELATIVE TO ATTENUATIONAT 20 DEGREES C.
4.2 STORAGE TEMPERATURE: -40 DEGREES C TO +50 DEGREES C WITH NO CHANGE IN ANY FIBRE OR CABLE PROPERTIES AFTER RETURN TO 20 DEGREES C.

MATERIAL —
FINISH —

UNLESS OTHERWISE NOTED:
1 ALL DIMS IN MILLIMETERS
2 2 DEC PLACES ±.25
3 1 DEC PLACES ±.50
4 ANGLES ±
5 ECCENTRICITY
6 SURFACE ROUGHNESS
275 max
REMOVE SHARP EDGES
0.37 max

NEXT ASSY
APPLICATION

CONTRACT NO
DRAWN
CHECKED
APPROVED
DATE 29 MAR 85

FOCAL MARINE LIMITED
110 BEDFORD HIGHWAY
BEDFORD NOVA SCOTIA

TITLE
CABLE, FIBREOPTIC,

SIZE DRAWING NO
B 3-8468-200-0

SCALE SHEET OF

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

5.0 SHIPPING CONFIGURATION

5.1 DRUM DIAMETER: >30 cm

5.2 CABLE ENDS: TO BE PROTECTED AGAINST MOISTURE PENETRATION OR MECHANICAL DAMAGE, AS APPROPRIATE. BOTH ENDS ACCESSIBLE FOR TESTING.

5.3 LENGTHS: THE LENGTH OF CABLE ON THE DRUM SHALL BE NOT LESS THAN 300 m UNLESS ORDERED IN SHORTER LENGTHS IN WHICH CASE IT SHALL BE IN THE LENGTH SPECIFIED. TOLERANCE ON LENGTH - 0 + 10%

6.0 ACCEPTANCE TEST REQUIREMENTS

6.1 VISUAL INSPECTION: EXAMINE CABLE FOR GENERAL CONFORMANCE TO REQUIREMENTS. NOTE ANY SIGNS OF DAMAGE, BLEMISHES ETC. RECORD OBSERVATIONS.

6.2 ATTENUATION: MEASURE AND RECORD THE ATTENUATION AT EACH WAVELENGTH WHILE THE CABLE IS STILL ON THE SHIPPING DRUM, USING THE HP8151A OR PHOTODYNE 22XLA POWER METER.
THE MEASURED ATTENUATION SHALL NOT BE MORE THAN 1 dB/km IN EXCESS OF THE MAXIMUM SPECIFIED ATTENUATION (SEE NOTES 1.4 AND 2.9)

MATERIAL

FINISH

UNLESS OTHERWISE NOTED:
ALL DIMS IN MILLIMETERS
2 DEC PLACES ±.05
1 DEC PLACES ±.0
ANGLES ± °
ECCENTRICITY [illegible]
SURFACE ROUGHNESS [illegible] max
REMOVE SHARP EDGES [illegible] max

NEXT ASSY | USED ON

APPLICATION

CONTRACT NO

FOCAL MARINE LIMITED
[illegible] BEDFORD HIGHWAY
BEDFORD NOVA SCOTIA [illegible]

DRAWN

CHECKED

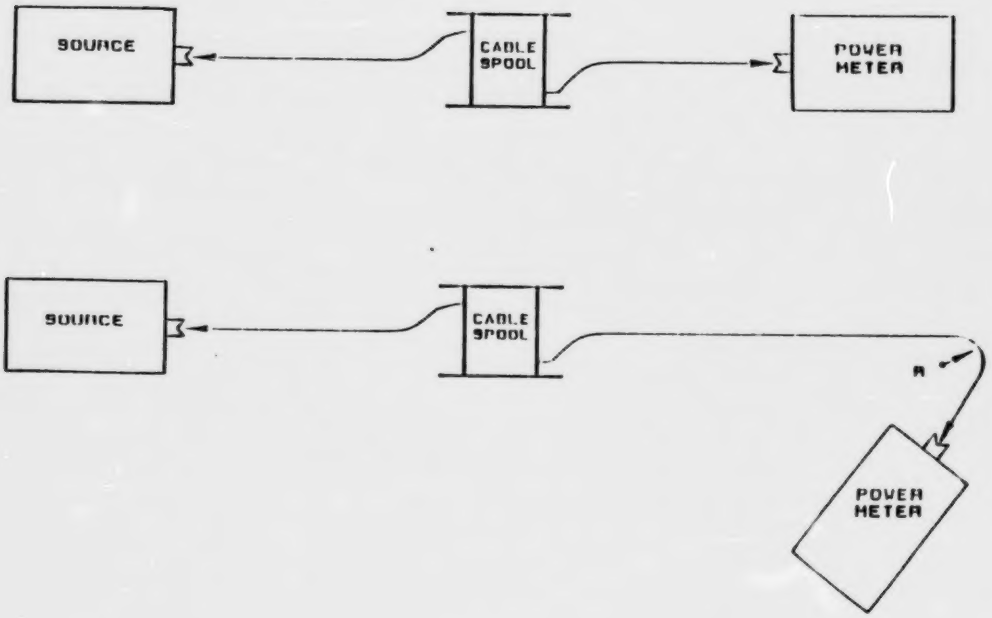
APPROVED

DATE
28 MAR 85

TITLE
CABLE, FIBEROPTIC,
[illegible]

SIZE | DRAWING NO
B 3-8468-200-0

SCALE NTS SHEET [illegible] OF [illegible]


SOURCE
CABLE SPOOL
POWER METER
SOURCE
CABLE SPOOL
R
POWER METER

LD CABLE (SIECOR)

Power before bending = -17.20 dBm
Power after bending = -17.20 dBm
R = 7.5 cm

Source - Math Associates @ 850 nm
Power Meter - HP @ 850 nm head

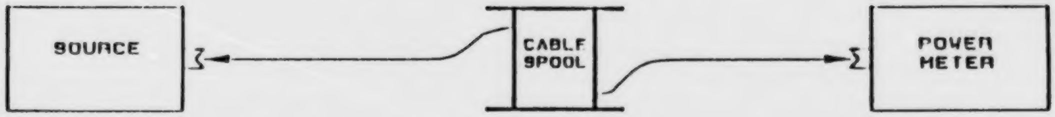
HD CABLE (WHITMOR)

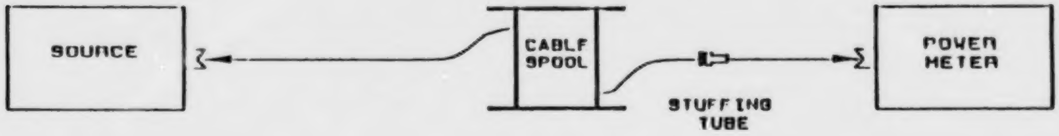
Power before bending = -22.97 dBm
Power after bending = -22.97 dBm
R = 12.3 cm

Results

Bending the cable, both Siecor and Whitmor , to the minimum bend radius, did not produce any measurable attenuation in either of the cables.

Figure A-1 Cable Bend Radius Test





Source - Math Associates @ 850 nm
Power Meter - HP with 850 nm head

Stuffing tube - Thomas and Betts 2522
- Kandu V012MP

LD (SEICOR) CABLE

Power before compressive load -17.20 dBm
Power with compressive load -17.20 dBm

HD (WHITMOR) CABLE

Power before compressive load -22.97dBm
Power with compressive load -22.97dBm

Description

Compressive load was exerted by applying greater than the normally required force to the nut of the stuffing tubes with a twelve inch wrench. Both the Thomas and Betts and Kondu tubes were used on both the Siecor and the Whitmor cables with the same results in all cases.

Results

Compressive loads within any normally expected limits do not cause any attenuation in the cable.

Figure A-2 Cable Compressive Loading Test

Transmissive Star Coupler Acceptance Test Results

Ref. Dwg. No. 3-8468-291-0
Make: Canstar
Model # PCS 4X4-100
Serial # 84-1274-P
Wavelength - 820 nm

		Input			
	Port	1	2	3	4
Output	A	7.06	6.92	5.26	6.96
	B	6.96	7.06	6.83	4.98
	C	5.19	6.91	6.69	5.71
	D	6.98	5.33	7.03	7.08

Insertion Loss dB

Make: Canstar
Model #PCS 4X4-100
Serial # 84-1274-P
Wavelength: 820 nm

		Input			
	Port	1	2	3	4
Output	A	7.34	5.82	8.06	7.68
	B	5.79	7.28	8.33	7.22
	C	7.75	7.62	5.10	8.02
	D	7.29	7.73	8.33	5.48

Insertion Loss dB

Note: Acceptance tests were conducted at 820 nm whereas the manufacturer's QA tests were conducted at 850 nm. Generally speaking, insertion loss is higher at shorter wavelengths.

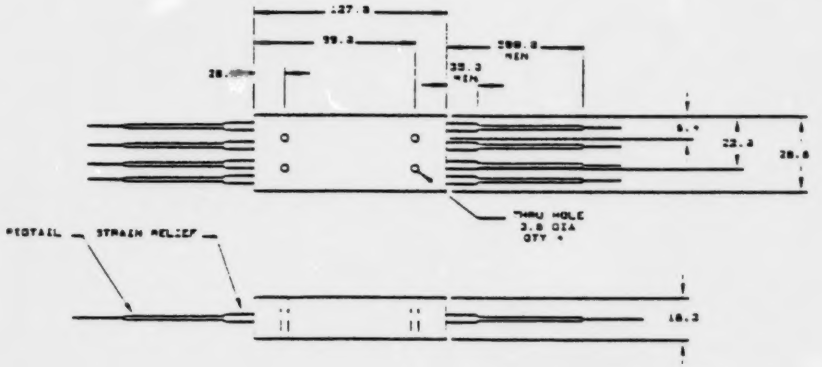
Transmissive Star Coupler Acceptance Test Results

Ref. Dwg. No. 3-8468-291-0

Dimension checks verified all dimensions to be within specified limits.

ZONE	LTR	DESCRIPTION	DATE	APPROVED

REVISIONS



1.0 SPECIFICATIONS

1.1 NUMBER OF PORTS: 4 INPUT , 4 OUTPUT

1.2 CONSTRUCTION: FUSED BICONICAL TAPER, TRANSMISSIVE STAR

1.3 DIMENSIONS AND MOUNTING: SEE FIGURE ABOVE

1.4 FIBRE: 100/140 MICRON, GRIN, GLASS, CP

1.5 CABLE: 8 x PIGTAILS, 3.3 mm DIA MAX, LOOSE TUBE CONSTRUCTION, KEVLAR REINFORCED POLYURETHANE JACKET

1.6 INSERTION LOSS (MAX) - 8 dB

1.7 VARIATION (MAX) - +/- 1 dB

1.8 WAVELENGTH OF OPERATION - 820 nm, 1300 nm

2.0 ACCEPTANCE TESTS:

2.1 INSERTION LOSS MEASUREMENTS WILL BE MADE AT 820 nm AND 1300 nm BETWEEN EACH INPUT AND ALL OUTPUT PORTS

2.2 SOURCES WILL BE:

- 820 nm SPECTRONICS SPX4140 OR AUGAT 690-23
- 1300 nm CODENOLL CODELINK 1

2.3 DETECTOR WILL BE A PHOTODYNE 22 XLA WITH 820 nm AND 1300 nm DETECTORS

2.4 DIMENSIONS WILL BE VERIFIED

MATERIAL
FINISH

UNLESS OTHERWISE NOTED:
1.0 DIMS IN MILLIMETRES
2.0 2 DEC PLACES ±0.25
3.0 1 DEC PLACES ±0.50
4.0 ANGLES ±1/2 DEG.
5.0 CONCENTRICITY .10 MAX
6.0 SURFACE ROUGHNESS 70 MAX
7.0 REMOVE SHARP EDGES .XX MAX

CONTRACT NO.
DRAWN
CHECKED
APPROVED
DATE 11-MAR-85

NEXT ASSY USED ON
APPLICATION

FOCAL MARINE LIMITED
1370 BEDFORD HIGHWAY
BEDFORD, NOVA SCOTIA, B4A 1E2

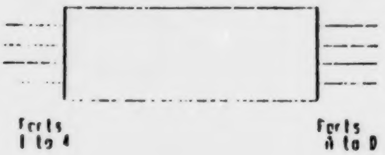
TITLE STAR COUPLER

SIZE DRAWING NO.
B 3-3468-391-0

SCALE NTS SHEET 1 OF 1

CANSTAR

FIBER OPTIC COUPLER Q.A. REPORT



STAR COUPLER TYPE :PCS 4*4-100
Customer Name :FOCAL MARINE LTD.
P.O. No. :23542
Sales Order No. :520823 REF: 1264
Date Tested :SEPTEMBER 18/84
Fiber Type :1508 CORNING
Serial No. :84-1050P

TOTAL PORT TO PORT LOSS (dB)

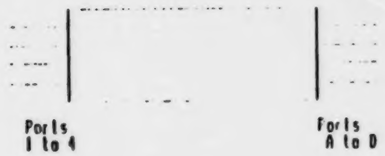
				INPUTS
PORTS	1	2	3	4
A	7.0	6.8	5.4	6.8
B	6.8	7.0	6.9	5.4
C	5.4	6.9	7.0	6.9
D	6.9	5.5	6.9	7.1

Measured at 650nm

Q.A.RELEASE..V.K...

CANSTAR

FIBER OPTIC COUPLER Q.A. REPORT



STAR COUPLER TYPE :FCS 444-100
Customer Name :FOCAL MARINE LTD
P.O. No. :5854
Sales Order No. :520309 REF.875
Date Tested :DECEMBER 10/84
Fiber Type :1500 CORNING
Serial No. :84-1274P

TOTAL PORT TO PORT LOSS (dB)

	INPUTS			
PORTS	1	2	3	4
A	7.1	5.9	7.7	7.4
B	5.9	7.0	7.7	7.0
C	7.4	7.0	4.7	7.6
D	7.0	7.4	7.9	5.4

Measured at 850nm

Q.A.RELEASE..V.K..

CANSTAR

DATA SHEET

FIBER OPTIC COUPLERS

TRANSMISSIVE STAR
TYPE PCS "N" X "N"

Canstar fiber optic transmissive star couplers are designed for use in optical local area networks, industrial control, data acquisition and data dissemination systems. Standard couplers are available in any input/output configuration up to 64 x 64 ports. Optimum performance and reliability under adverse environmental conditions is achieved through a proprietary refinement of the fused biconical taper technique coupled with rigid quality control and testing.

FEATURES
- Compact rugged package
- Completely non-metallic
- PC board or chassis mountable
- Bi-directional
- Low insertion loss
- High directivity
- Good uniformity
- Step or graded index fibers
- Jacketed or bare fiber pigtails
- Optional connectorized pigtails
- Optional rack or table top enclosure with connectors

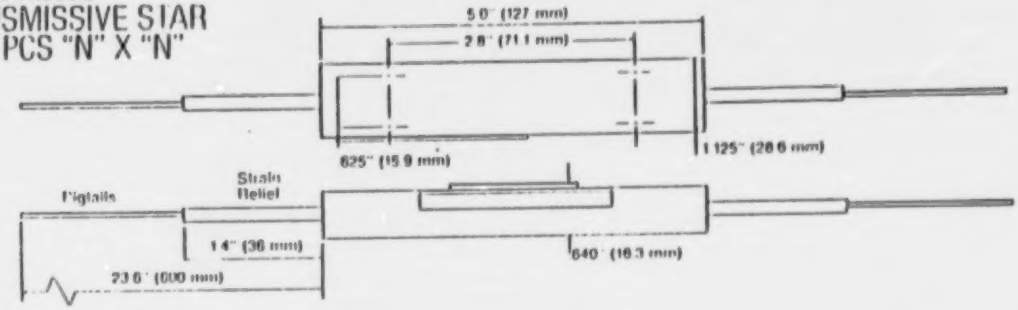
CANSTAR

DATA SHEET

FIBER OPTIC COUPLERS

TRANSMISSIVE STAR
TYPE PCS "N" X "N"

DIMENSIONS


5.0" (127 mm)
2.8" (71.1 mm)
.625" (15.9 mm)
1.125" (28.6 mm)
Pigtails
Strain Relief
1.4" (36 mm)
.640" (16.3 mm)
23.6" (600 mm)

Canstar fiber optic couplers are passive devices usable with wavelengths between 400 nm and 1500 nm. Engineered to withstand industrial environments, the devices are enclosed in a flame resistant rugged housing. Pigtails can be provided with 250 micron SCPC coating only or additional buffer tubes or buffer tubes and Kevlar reinforced polyurethane jacketing depending on the number of fibers. A variety of connectors and enclosures can be provided.

TYPICAL CHARACTERISTICS

GENERAL

Temperature:	-50°C to +85°C
Humidity:	to 98% @ +85°C
Shock:	>15 g

JACKETING

Up to 12×12 ports — 3 mm PU jacketing
Up to 16×16 ports — 1.2 mm TFE buffer
Over 16×16 ports — 250 micron SCPC coated fiber

FIBER

	Core (μm)	O.D. (μm)	NA	Index
Standard	50	125	0.2	G.I.
	85	125	0.26	G.I.
	100	140	0.3	G.I.
	100	140	0.29	S.I.

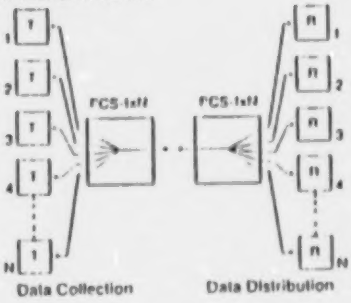
Optional: Other fiber types available on a custom basis

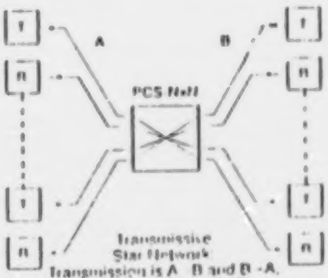
PERFORMANCE

Type	Maximum Loss Port to port (dB)
PCS 4×4	8.0
PCS 8×8	11.5
PCS 16×16	16.0
PCS 32×32	19.0
PCS 64×64	23.0

Characteristics of other types available upon request

APPLICATIONS


T
1
2
3
4
N
PCS-NxN
PCS-NxN
R
1
2
3
4
N
Data Collection
Data Distribution


T
R
A
B
PCS NxN
T
R

Transmissive Star Network
Transmission is A→B and B→A, but not A→A and B→B

ORDERING INFORMATION

Specify
- No. of Input and Output Ports
- Fiber Size
- G.I. or S.I. for 100 μm
- Jacketing

Example - PCS 4×4 - 100 G.I. 1.2 mm TFE

Optional
- Connectors
- Chassis Mounted

DISTRIBUTED BY

CANSTAR COMMUNICATIONS
1240 Ellesmere Road, Scarborough,
Ontario, Canada M1P 2X4
Tel (416) 293-7722
Telex 065-25403
FAX (416) 293-5756
A division of Canada Wire and Cable Limited

Optical Assembly Test Results

Ref. Dwg. No. 1-8468-017-0 Fibre Optic Layout, Fusion Splice
1-8468-018-0 Fibre Optic Layout, Mechanical Splice
3-8468-253-0 WDM Specification
Date: February 7, 1985
Manufacturer: JDS
Part No.: 813

As a result of design modifications, the optical assemblies, in their final configuration, consisted of two, independent wavelength division multiplexers/demultiplexers (WDM) mounted on one board. Consequently, the assembly test results are given by the acceptance test results for these items. The results are grouped to identify the WDM's that were mounted together in the final installation.

Assembly Fusion #1 Location LBR S/N1002

W2 S/N FM 1	Source (nm)	Source Power (dBm)	Input Port	Output Port	Measured Power (dBm)	Value (dB)
	1300	19.4	1300	I/O	21.0	0.6
	1300	19.5	I/O	1300	20.9	0.4
	1300	--	1300	820	>69.6	>50
	1300	20.9	I/O	820	49.7	28.8
	820	17.0	820	I/O	18.6	1.6
	820	17.0	I/O	820	18.5	1.5
	820	--	820	1300	>134	>90
	820	--	I/O	1300	>130	>90

W1 S/N FM 6	Source (nm)	Source Power (dBm)	Input Port	Output Port	Measured Power (dBm)	Value (dB)
	1300	19.6	1300	I/O	21.9	2.3
	1300	19.6	I/O	1300	21.4	1.8
	1300	--	1300	820	>68.0	>50
	1300	21.6	I/O	820	48.6	27.0
	820	16.2	820	I/O	17.8	1.6
	820	16.3	I/O	820	17.6	1.3
	820	--	820	1300	>138	>90
	820	--	I/O	1300	>138	>90

Optical Assembly Test Results

Assembly Fusion #2 Location MCR S/N 1003

W2 S/N FM 5	Source (nm)	Source Power (dBm)	Input Port	Output Port	Measured Power (dBm)	Value (dB)
	1300	19.5	1300	I/O	20.8	1.3
	1300	19.5	I/O	1300	20.7	1.2
	1300	--	1300	820	>70.0	>50
	1300	20.8	I/O	820	49.1	28.3
	820	16.4	820	I/O	18.0	1.6
	820	16.4	I/O	820	17.9	1.5
	820	--	820	1300	>137	>90
	820	--	I/O	1300	>133	>90

W1 S/N FM 2	Source (nm)	Source Power (dBm)	Input Port	Output Port	Measured Power (dBm)	Value (dB)
	1300	19.4	1300	I/O	20.7	1.3
	1300	19.4	I/O	1300	20.8	1.4
	1300	--	1300	820	>70.0	>50
	1300	20.7	I/O	820	48.1	27.4
	820	16.4	820	I/O	17.6	1.2
	820	16.4	I/O	820	17.8	1.4
	820	--	820	1300	>136	>90
	820	--	I/O	1300	>133	>90

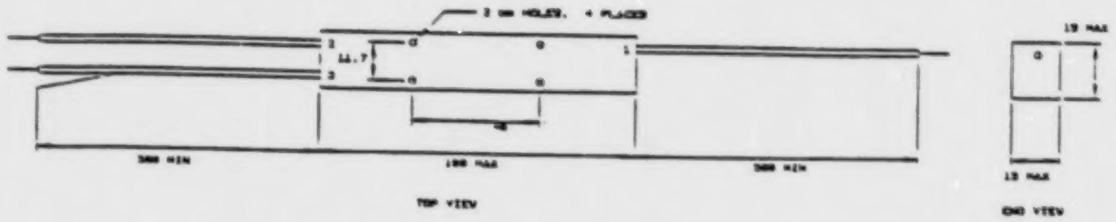
Optical Assembly Test Results

Assembly Mechanical #1   Location Bridge   S/N1001

W2 S/N FM 3	Source (nm)	Source Power (dBm)	Input Port	Output Port	Measured Power (dBm)	Value (dB)
	1300	19.3	1300	I/O	20.3	1.0
	1300	19.4	I/O	1300	20.5	1.4
	1300	--	1300	820	>65.8	>50.0
	1300	20.5	I/O	820	47.7	27.2
	820	16.4	820	I/O	17.6	1.2
	820	16.4	I/O	820	17.3	0.9
	820	--	820	1300	>136	>90
	820	--	I/O	1300	>130	>90

W1 S/N FM 4	Source (nm)	Source Power (dBm)	Input Port	Output Port	Measured Power (dBm)	Value (dB)
	1300	19.4	1300	I/O	20.7	1.3
	1300	19.4	I/O	1300	20.5	1.1
	1300	--	1300	820	>71.2	>50
	1300	20.6	I/O	820	47.9	27.3
	820	16.5	820	I/O	18.2	1.6
	820	16.5	I/O	820	18.2	1.5
	820	--	820	1300	>136	>90
	820	--	I/O	1300	>135	>90

Optical Assembly Test Results



1.0 SPECIFICATIONS

1.1 MOUNTING HOLES ARE FOR M2 SOCKET HEAD SCREWS. OTHER MOUNTING ARRANGEMENTS ARE ACCEPTABLE IF THEY SATISFY THE DIMENSIONS
1.2 CABLED PIGTAILS, 3.0 mm MAXIMUM DIAMETER. CABLE IS LOOSE TUBE CONSTRUCTION, KEVLAR REINFORCED, POLYURETHANE
1.3 FIBRE IS CORNING 100/140 GI, CPC BUFFER
1.4 TWO WAVELENGTHS: 820 nm AND 1300 nm
1.5 FOR USE WITH LIGHT EMITTING DIODES
1.6 IT IS PREFERRED BUT NOT NECESSARY THAT PORT 2 OR 3 BE THE INPUT PORT TO THE WDD
1.7 INSERTION LOSS: < 1.5 dB
1.8 ISOLATION, ALL PORTS: > 20 dB
1.9 CROSSTALK, ALL PORTS: BETTER THAN -35 dB
1.10 TEMPERATURE RANGE: 0 TO 60 C
1.11 MOUNTING HOLES ARE TO BE CENTERED ON THE WDD BODY

2.0 ACCEPTANCE TESTS

2.1 INSERTION LOSS WILL BE MEASURED AT 820 AND 1300 nm
2.2 CROSSTALK WILL BE MEASURED
2.3 ISOLATION WILL BE MEASURED
2.4 DIMENSIONS WILL BE VERIFIED
2.5 SOURCES WILL BE:
- 820nm SPECTRONICS SPX 4149 OR AUGAT 690-[illegible]
- 1300nm CODENOLL CODELINK-1
2.6 DETECTOR WILL BE A PHOTODYNE 22XLA WITH A 820 nm AND A 1300 nm DETECTOR AS REQUIRED

3.0 DEFINITIONS

CROSSTALK - THE AMOUNT OF LIGHT OF ONE WAVELENGTH REACHING THE OUTPUT OF A DIFFERENT WAVELENGTH IN A WDD MUST BE SPECIFIED FOR EACH WAVELENGTH COMBINATION.
ISOLATION - THE AMOUNT OF LIGHT OF ONE WAVELENGTH REACHING THE INPUT OF A DIFFERENT WAVELENGTH IN A WDM MUST BE SPECIFIED FOR EACH COMBINATION OF WAVELENGTHS.

MATERIAL
FINISH

UNLESS OTHERWISE NOTED:
1 ALL DIMS IN MILLIMETERS
2 2 DEC PLACES ±0.25
3 1 DEC PLACES ±0.50
4 ANGLES ±1°
5 CONCENTRICITY [illegible]
6 SURFACE ROUGHNESS [illegible]
7 [illegible]

APPLICATION

CONTRACT NO

FOCAL MARINE LIMITED
173 BEDFORD HIGHWAY
BEDFORD NOVA SCOTIA [illegible]

DRAWN
CHECKED
APPROVED
DATE MAR 9/85

TITLE
WDM/WDD SPECIFICATION

SIZE B DRAWING NO 3-8468-253-0

SCALE NTS SHEET 1 OF 1

JDS Optics inc

SINGLEMODE/MULTIMODE WAVELENGTH DIVISION MULTIPLEXERS/DEMULTIPLEXERS

Features

- low insertion loss
- good crosstalk
- rugged design
- multimode and singlemode fibers
- 2 and 3 channel devices standard
- custom designs available

PERFORMANCE SPECIFICATIONS

Model	Channels	Operational Wavelengths (um)	Insertion Loss Per Pair/Channel		Isolation (dB)
			multimode	singlemode	
WD813	2	CH1: 0.80 - 0.87 CH2: 1.15 - 1.60	≤ 2.0		≤ - 20 ≤ - 28
WD1213A	2	CH1: 1.20 - 1.24 CH2: 1.30 - 1.34	≤ 2.7	≤ 3.0	≤ - 28
WD1213B	2	CH1: 1.250 - 1.270 CH2: 1.315 - 1.340	≤ 3.0	≤ 3.5	≤ - 20
WD1315A	2	CH1: 1.30 - 1.34 CH2: 1.48 - 1.52	≤ 3.0	≤ 3.5	≤ - 25
WD1315B	2	CH1: 1.275 - 1.340 CH2: 1.525 - 1.600	≤ 3.0	≤ 3.5	≤ - 25
WD235	3	CH1: 1.20 - 1.24 CH2: 1.30 - 1.34 CH3: 1.48 - 1.52	≤ 3.5	≤ 4.0	≤ - 25
WD123	3	CH1: 1.05 - 1.11 CH2: 1.20 - 1.24 CH3: 1.30 - 1.34	≤ 3.5		≤ - 25

Other Device Types

- custom wavelength channel allocation
- multichannel grating based designs
- low cost production designs

FIBER

- multimode - 50 um core/125 um OD, 0.2 NA, graded index
- singlemode - 9 um core/125 um OD, 0.1 NA
- other fiber types available

PO BOX 6706, STATION J, OTTAWA, ONT., CANADA, K2A 3Y1 (613) 727 1303 TELEX 053 4597

Video Fibre Optic Transmission System Test Results

Date: July 31, 1986

Manufacturer: Optelecom

Model: Transmitter 3100T
Receiver 3100R

The frequency response of the transmitter and receiver was tested and found to be within a 3 dB range, from 10 Hz to 13MHz. This is beyond the specified response range.

The transmitter output power was measured to be -11.4 dBm and the receiver sensitivity was measured at -40.8 dBm, giving a flux budget of 29.4 dB. This budget exceeded the flux losses for the link from the aft mast to the machinery control room (MCR) node.

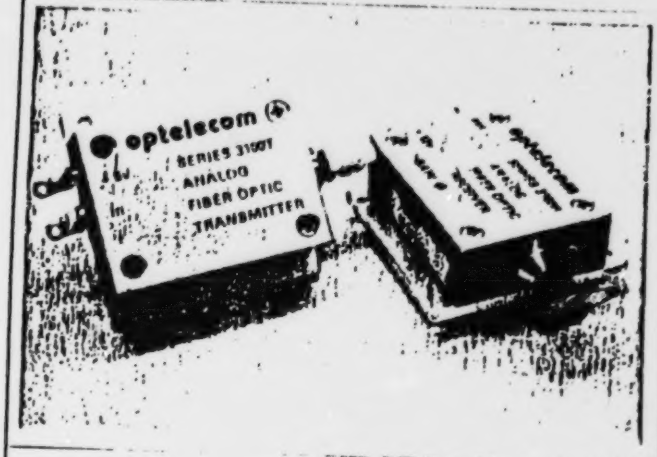
The system was operated over a 0 degrees C to 55 degrees C range and found to work satisfactorily. Although the transmitter will be located in an outboard enclosure, the enclosure has a heater fitted inside. When tested with the transmitter mounted inside the camera and fitted inside the enclosure, the transmitter operated well with the ambient temperature at 0 degrees C. At that external temperature, the internal temperature of the camera enclosure held at 19 degrees C. Thus, with the enclosure heater and the heat generated by the camera and transmitter, the temperature of the transmitter is not likely to drop below 0 degrees C, the low end of the tested range.

Operation of the video link, complete with the camera and monitor revealed that the camera was overdriven by bright sunlight and that the transmitter, under bright light conditions, would overdrive the receiver. The camera was adjusted to the maximum limits of its performance under bright light conditions. Also, the transmitter output power was reduced and the receiver sensitivity was reduced to provide optimum performance over the entire ambient light range.

optelecom
The Optical Communications Company

ANALOG FIBER OPTIC MODULES

DESIGNER SERIES 3100


optelecom
SERIES 3100T
ANALOG
FIBER OPTIC
TRANSMITTER

Features

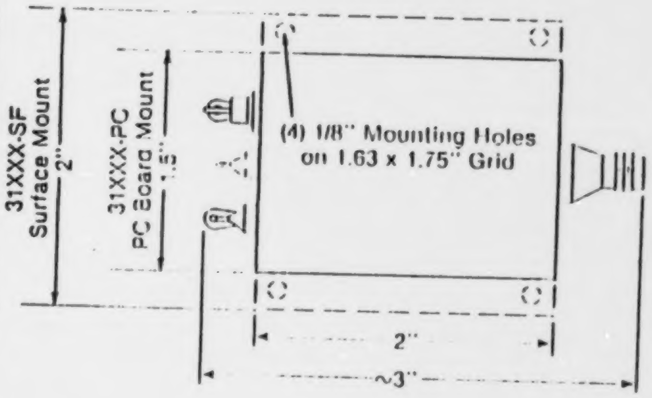
- CCTV Compatible
- Full RF Shielding
- Many Mounting Options
- Rugged Packaging
- Single Voltage Powering

Description

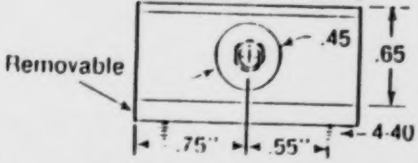
These modules furnish a system designer with proven components specifically tailored to allow easy integration into a wide variety of hardware designs. The total R.F. shielding (including R.F. electrical feed throughs), which is integral to the module case, insures that any external electrical disturbance such as operation of switches, motors, or relays will not affect module operation. This feature, therefore, extends one of the key benefits of optical fiber communication—the freedom from data transmission problems caused by RFI, EMI, and equipment voltage differentials—to the electro-optic terminal units.

The optical port is a female Amphenol 905 Series. All exterior surfaces are capable of resisting harsh environments. The module case and covers are fabricated from aluminum treated for corrosion protection. Cover and connector screws are stainless steel; the connector shell is nickel-plated brass.

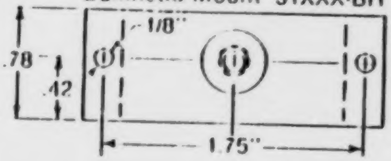
The internal printed circuit board is secured directly to the case at multiple mounting points to provide a rugged, shock-resistant package. Additional vibration, moisture and shock resistance for military applications can be supplied as an option by using conformal circuit coatings and light weight foam for total component protection.


31XXX-SF
Surface Mount
2"
31XXX-PC
PC Board Mount
1.5"
(4) 1/8" Mounting Holes
on 1.63 x 1.75" Grid
2"
~3"

PC Mount 31XXX-PC


Removable
.45
.65
.75"
.55"
4-40

Bulkhead Mount 31XXX-BH



Scientific Data Highway (SDH)
Acceptance Test Report - Test 2.3.2

Purpose

Acceptance test 2.3.2 for the SDH (specification control drawing 1-8468-200-0) was proposed to determine the increase in response time and decrease in throughput caused by the addition of the electrical SDH between an IEEE-488 controller and an IEEE-488 device (bus extension configuration). The rationale for this test was to provide a benchmark for user IEEE-488 applications and as partial verification of the electrical network performance before acceptance of the supplier product and implementation of the fibre optic transmission option.

This report presents the test results as demonstrated by the supplier (SEIMAC LIMITED) on 1986 02 06. Also included is a brief discussion of the significance of the results.

Test Configuration

Figure A-3 depicts the conventional IEEE-488 controller to device configuration. The IEEE-488 interface provides for data transfer (parallel ASCII) and control via various signalling lines as defined by the standard. In this case, the controller was an Eagle Spirit PC (IBM PC clone) with a Ziatech 1488A IEEE 488 interface card. The IEEE-488 interface is programmed, controlled and interrogated using the BASIC software language and several network transport subroutines which would be supplied to the SDH user. The IEEE-488 device for this test was a Tandberg TDC 3000 tape drive.

For the first part of the test, the controller was programmed to rewind the tape, write a 16 character message to the tape drive, rewind the tape again and then read the message back to the controller (program attached). The total transaction time was measured using a real time clock on the Ziatech card, from the BASIC program. Figure A-5 presents the IEEE-488 bus transfers needed to effect this test.

Figure A-4 shows the configuration with the SDH introduced as a bus extender. The same program as before was modified to include the additional "call set-up" required between the two nodes. Figure A-6 describes the IEEE-488 bus and internodal EIA RS 422 transfers required to effect the second part of this test.

Results

The total transaction time for the direct set-up was 3.37 seconds averaged over 25 iterations. The tape rewinds and record dominated the transaction duration.

For the SDH configuration, the transaction time was 5.75 seconds.

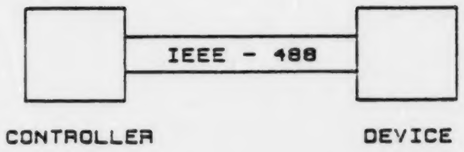

IEEE - 488
CONTROLLER
DEVICE

Figure A-3 IEEE-488 Controller to Device Configuration

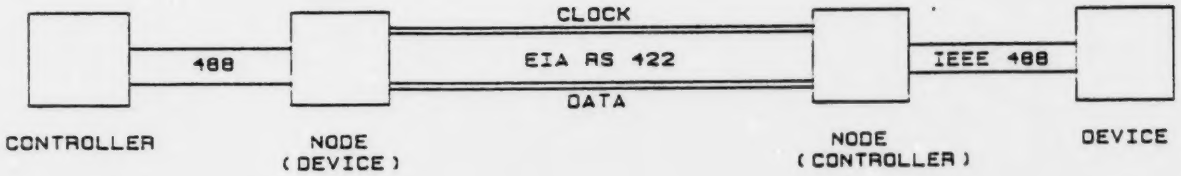

CLOCK
488
EIA RS 422
IEEE 488
DATA
CONTROLLER
NODE
(DEVICE)
NODE
(CONTROLLER)
DEVICE

Figure A-4 SDH in Controller to Device Configuration

Discussion

The SDH adds approximately 70% to the total transaction time for the described situation.

The incremental transaction time was dominated by the overhead required to achieve call set-up while maintaining the true IEEE-488 control structure between four devices instead of two. At a transmission rate of 500 kbps, the internodal packet transmission time (12 packets x 256 bytes x 8 bits/500 kpbs = 0.049 sec) appears to constitute only a small portion of the increase (2.38 sec). As for any IEEE-488 system, the slowest device on the bus determines the overall network performance which is perceived by the user. It is expected that some improvement (possibly 30%) could be had by replacing the interpretive BASIC routines with assembly code.

Conclusion

Acceptance test 1-8468-200-0/2.3.2 was demonstrated satisfactorily by the supplier. Although response time and throughput in their usual sense were not determined the described test demonstrated the consistent IEEE-488 implementation and the overall effect on the user application in terms of call set-up overhead and transaction delay. It is felt that the SDH network performance will be imperceptible to the user even under severe collision conditions and that any delay resulting from networking will be far outweighed by the flexibility provided. This will certainly be the case for the three node Coast Guard installation.

Recommendation

As it appears that the user perceived SDH performance is somewhat device dependent, it is recommended that further testing of this type be performed using other available IEEE-488 devices, in particular, both slow mechanical ones and fast electrical ones.

A more rigorous acceptance package is required to fully test the hardware and software under all imaginable normal and abnormal operating situations. This should include exercising all IEEE-488 command situations and all device types and combinations as is practically possible. This would be the normal procedure when new software generics or hardware modifications are released.

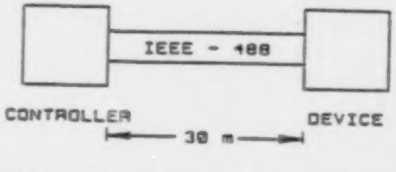
```
Controller          (IEEE-488, parallel     Device
                    ASCII)

     CT  DL                 ------>
BS (16)  RW   CR  LF        ------>
     CT  DL                 ------>
TANDBERG      CR  LF        ------>
     CT  DL                 ------>
WE   RW  CR  LF             ------>
    CL  DT                  ------>
                          <------           TANDBERG CR LF LF
                                            LF LF LF LF LF
```

CT DL	controller talk device listen
BS	block size
RW	rewind tape
WE	write end of file

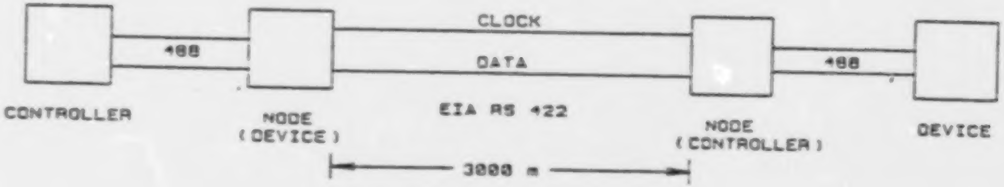
Figure A-5 IEEE-488 Bus Transfer

```
Controller          Node              Node            Device

       (IEEE 488,       (RS 422,           (IEEE 488,
       parallel ASCII)  256 byte packets)  parallel ASCII)

10 bytes remote ------>
device: operation

                     256 bytes ------->
                                      NT DL -------->
                            <---------- ACK

BS(16) RW -------->

                     256 bytes -------->

                                      BS(16) RW CRLF ----->
                               <-------- ACK

TANDBERG CRLF ------>

                     256 bytes --------->

                                      TANDBERG CR LF------>
                            <--------- ACK

WE RW CR LF -------->

                     256 bytes ---------->
                                             NL  DT -------->
                              <---------- ACK

                                     <--------TANDBERG CR LF


                            <----------- 256 bytes

     <------------- TANDBERG CR LF

                            -----------> ACK
```

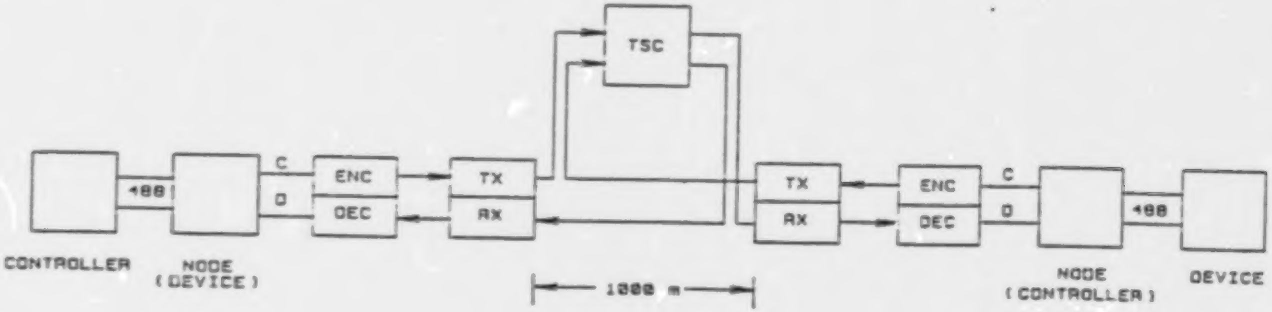
Figure A-6 IEEE-488 Bus and Internodal EIA RS 422 Transfer


IEEE - 488
CONTROLLER
DEVICE
30 m

- PARALLEL ASCII BUS FOR DATA TRANSMISSION AND CONTROL OF INSTRUMENTATION


CONTROLLER
488
NODE (DEVICE)
CLOCK
DATA
EIA RS 422
NODE (CONTROLLER)
488
DEVICE
3000 m

- CALL SET-UP REQUIRED
- RESPONSE TIME DICTATED BY SLOWEST DEVICE NOT PACKET TRANSMISSION


CONTROLLER
488
NODE (DEVICE)
C
D
ENC
DEC
TX
RX
TSC
TX
RX
ENC
DEC
C
D
NODE (CONTROLLER)
488
DEVICE
1000 m

- ENCODING OF CLOCK AND DATA REQUIRED
- ADDITIONAL NODES SUPPORTED BY CSMA/CD

Figure A-7 Electronic Data Highway

Digital Transmitter Test Results

Pre-Installation Test Results

S/N	Test No. 1 LED Current (mA)	Test No. 1 O/P Power (dBm)	Test No. 2 O/P Power (dBm)
3001	231	-14.10	-16.20
3002	230	-13.80	-16.00
1268	209	-15.66	-17.13

Post Trial Test Results

S/N	Card No.	Location	Test No. 3 O/P Power (dBm)
3001	002	LBR	-22.80
3002	001	Bridge	-17.14
1268	003	MCR	-17.42

Test No. 1 - Duty cycle = 100%
- Transmitters mounted on Meret test card

Test No. 2 - Test signal = $2^{15} - 1$ pseudo-random pattern
- Transmitters mounted on Meret test card

Test No. 3 - Test signal = 1 Mbit TTL with 50% duty cycle
- Transmitters mounted on digital cards

Appendix B

Page

Environmental Test Report B-2

Environmental Test Report

1.1 Introduction

Environmental testing included both vibration and temperature cycling as per the environmental test plan, subtask 1.9.3, task 1.9.

1.2 Analysis

Vibration

The first system to be tested was the LBR node consisting of its data highway and optical board, containing fusion splices, designated #2. Also included was the star coupler enclosure, designated heavy duty.

Test conditions were as follows:

Frequency (Hz)	Displacement (in)	Acceleration Range (g)
5-15	.03	.01 to .35
10-24	.02	.25 to .65
25-33	.01	.35 to .55
34-40	.005	.30 to .41
41-49	.003	.26 to .39

The frequency interval was every 2 Hz. Following the variable vibration analysis a vibration sweep from 50 to 200 Hz at 2g acceleration was carried out over a period of 30 minutes.

The second system to be tested was the bridge node consisting of the data highway and the optical board, containing the mechanical splices. Also included was the star coupler enclosure designated light duty.

Test conditions were the same as for the first system.

1.3 Test Plan Deviations - Vibration

1. Testing commenced at approximately 10 Hz frequency due to the sensitivity of the test equipment used.
2. Only two data highways were tested because the similarities in design were expected to produce results representative of all three.
3. The video unit assembly was not vibration tested because the system was not available.

1.4 Results

1.4.1 The results of the post testing mechanical inspection of the LBR node system are included (see Annex).

No post testing system verification was done on the LBR node due to the mechanical failure of the system during vibration.

The components which broke free during the LBR node were tacked down in all three nodes before continuing the tests (see Annex for details).

1.4.2 The results of the post testing mechanical inspection of the bridge node system are as follows:

Post test analysis -
all components in place. No loose piece parts or hardware. See also report 8551 - 3.4.

Star Coupler Enclosure -
see section from star coupler enclosure-heavy duty (see Annex).

2.0 ANALYSIS - TEMPERATURE

Testing originally began at NSRFC but due to problems getting the system up and operating properly the temperature chamber was moved to Focal Marine Limited facilities to resume testing.

Test configuration as per attached sheet (page 7).

2.1

The first system that was tested was the MCR node consisting of the data highway and the optical board containing the fusion splice assembly designated as #2. Also included was the star coupler enclosure designated as the light duty enclosure.

Results

Video	Digital
picture deterioration at 42 C picture deterioration at 5 C OK between those temperatures. This is consistent throughout test.	in sync +55 C loses sync during 0 C soak

This system was retested 2 days later at low temperature only, and it failed again at 0 degrees C. The CPU card was suspected.

The system was retested 3 days later. The digital board was not available. The video and data highway (CPU) were monitored. The video quality was good between +12 and +28 degrees C. The data highway system checked out well.

2.2

The second system that was tested was the LBR node designated as #1 consisting of the data highway equipment and the optical board containing the fusion splice assembly designated as #1. Also included was the star coupler enclosure designated as the heavy duty enclosure.

Results

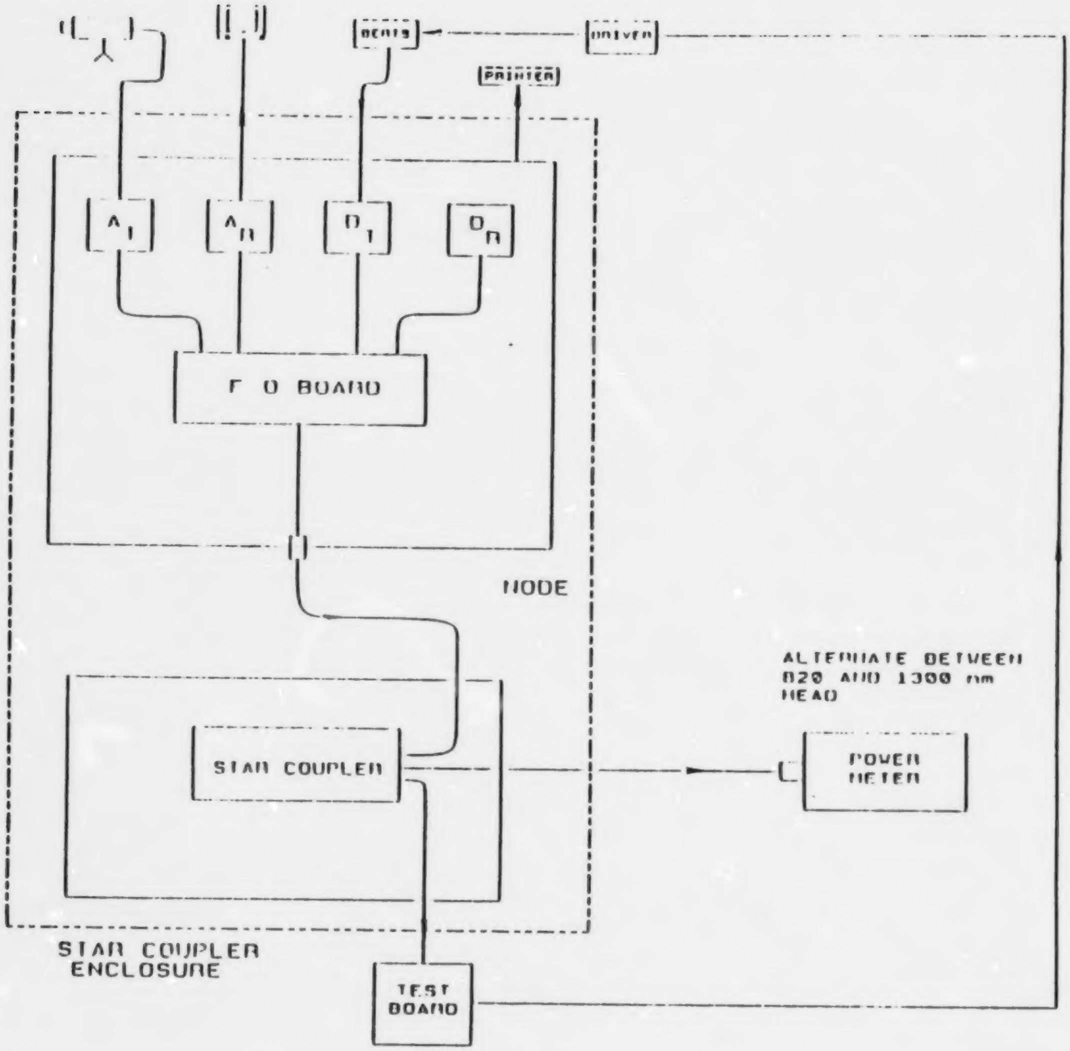
The digital board was not available. The video quality was good between +8 and +35 degrees C. Data highway system checked out well.

2.3

The third system that was tested was the Bridge node including the optical board containing the mechanical splice assembly. Also included was the star coupler enclosure designated as the light duty enclosure.

Results

The digital board was not available. The video quality was good between +8 and +37 degrees C. Data highway system checked out well.


BERTS
DRIVER
PRINTER
A T
A R
D T
D R
F O BOARD
NODE
STAR COUPLER
ALTERNATE BETWEEN 820 AND 1300 nm HEAD
POWER METER
STAR COUPLER ENCLOSURE
TEST BOARD

Temperature Test Configuration

Annex to Task 3.4
Scientific Data Highway

Post Vibration Analysis

Damage/Observations and Actions Taken

1. Front Panel

The leads to the "Remote not Responding" LED were broken. One lead to the reset button was broken. The mounting hardware of the "node" and "link" status LEDs was "finger" removable. No thread locker was evident. The hardware holding the reset button was loose.

2. Power Supply and Board

Capacitors C4, C25, C41 and C49 were free of the circuit board. All of the remaining capacitors were loose. One standoff support had not been installed. Considerable wear was evident on the back 2 standoffs. One of the lock washers securing the transformer was broken.

3. Rear Panel

The metal oxide varistor was broken free from the power cord plug and fuse.

Comments

All the enclosure support panels developed noticeable and sometimes noisy movement at certain frequencies. These panels were then stiffened via the addition of mounting hardware, support brackets and standoffs in the areas required. Extra support hardware was added in the area supporting the power supply transformer. All large components were properly secured to the circuit board using a suitable adhesive.

All hardware was changed to stainless steel type. Hardware, one size larger, was used to mount the power supply transformer. The missing standoff support was installed.

Star Coupler Enclosure

Post Vibration Analysis

Damage and/or Observations

1. Stress cracks were evident in the loose tube where it entered the splice tray.
2. The plexiglass was crazed around one of the mounting holes.

Comments:

Top "L" panel produced severe movement and noise during both the vertical and longitudinal axis vibration tests. The optical performance was not affected throughout. Structural stiffening was required in the area of the "L" panel as well as the horizontal brace located at the rear.

No damage or severe wear to the mounting platform was evident.

Appendix C

INSTALLATION TEST RESULTS

	Page
System Crosstalk Test Sheets	C-2
Optical Power Test Report	

System Crosstalk Test Sheet - Bridge Node

Transmitter power (820 nm) -10.1 dBm

Transmit node	Transmit (nm)	Receive node	Receive (nm)	Power (dBm)	Crosstalk (dB)
Bridge	820	MCR	1300	-52.0	41.9
Bridge	820	LBR	1300	-51.6	41.5
Bridge	820	Bridge	1300	-51.6	41.5

Transmitter power (1300 nm) -17.9 dBm

Transmit node	Transmit (nm)	Receive node	Receive (nm)	Power (dBm)	Crosstalk (dB) *
Bridge	1300	MCR	820	-120.0	>29.1
Bridge	1300	LBR	820	-132.0	>29.1
Bridge	1300	Bridge	820	- 80.0	>29.1

Crosstalk (dB) = Transmitter power (dBm) - Power (dBm)

* See note on MCR Report.

XTalk > -17.9 -(-47.0) = 29.1

XTalk > 29.1 dB

System Crosstalk Test Sheet - MCR Node

Transmitter power (820 nm) -11.5 dBm

Transmit node	Transmit (nm)	Receive node	Receive (nm)	Power (dBm)	Crosstalk (dB)
MCR	820	MCR	1300	-57.8	46.3
MCR	820	LBR	1300	-57.2	45.7
MCR	820	BRIDGE	1300	-53.1	41.6

Transmitter power (1300 nm) -18.6 dBm

Transmit node	Transmit (nm)	Receive node	Receive (nm)	Power (dBm)	Crosstalk (dB)
MCR	1300	MCR	820	-128.0	*>28.4
MCR	1300	LBR	820	-126.0	>28.4
MCR	1300	BRIDGE	820	-120.0	>28.4

Crosstalk (dB) = Transmitter power (dBm) - Power (dBm)

*NOTE: The 820nm power measurements were made with a Photodyne 22XLA power meter with a model 150 detector head. This head has a range of -90 to +3 dB.

The 1300 nm power measurements were made with a Photodyne 22XLA power meter with a model 550 detector head. This head has a range of -47 to 0 dBm. Thus, any measurements below -47 dBm are not valid. Therefore the crosstalk is -18.6 dBm -(-47.0 dBm) = 28.4 dB

XTalk > 28.4 dBm

System Crosstalk Test Sheet - LBR Node

Transmitter power (820 nm) -26.9 dBm

Transmit node	Transmit (nm)	Receive node	Receive (nm)	Power (dBm)	Crosstalk (dB)
LBR	820	MCR	1300	-53.1	26.2
LBR	820	LBR	1300	-52.3	25.4
LBR	820	BRIDGE	1300	-53.8	26.9

Transmitter power (1300 nm) -19.7 dBm

Transmit node	Transmit (nm)	Receive node	Receive (nm)	Power (dBm)	Crosstalk (dB)
LBR	1300	MCR	820	-127.0	* >27.3
LBR	1300	LBR	820	-130.0	>27.3
LBR	1300	BRIDGE	820	-122.0	>27.3

Crosstalk (dB) = Transmitter power (dBm) - Power (dBm)

*See note on MCR Report.

XTalk > -19.7 -(-47.0) = 27.3 dB

XTalk > 27.3 dB

OPTICAL POWER TEST REPORT

DATE: 25/03/86

OPERATORS: John Mayich

Mike Jerrett

TRANSMIT NODE: bridge

WAVELENGTH: 820 nm

OPTICAL ASSEMBLY OUTPUT POWER: -10.1 dBm

RECEIVE POWER:(dBm) SYSTEM
LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	-25.8	-26.1
LBR	-23.3	-24.6
Bridge	-27.2	-29.8
Star	-19.7	-17.6

	CABLE	
Link	H.D.	L.D.
bridge-MCR	15.7	16.0
bridge-LBR	13.7	14.5
bridge-Bridge	17.1	19.7
bridge-Star	9.6	7.5

WAVELENGTH: 1300 nm

OPTICAL ASSEMBLY OUTPUT POWER: -17.9 dBm

RECEIVE POWER:(dBm)

	CABLE	
Rx node	H.D.	L.D.
MCR	-30.9	-32.7
LBR	-32.3	-32.1
Bridge	-28.4	-31.8
Star	-22.3	-20.8

SYSTEM LOSS:(dB)

	CABLE	
Link	H.D.	L.D.
bridge-MCR	13.0	14.8
bridge-LBR	14.4	14.2
bridge-Bridge	10.5	13.9
bridge-Star	4.4	2.9

OPTICAL POWER TEST REPORT

DATE:25/03/86

OPERATORS: John Mayich

Mike Jerrett

TRANSMIT NODE: MCR

WAVELENGTH: 820 nm

OPTICAL ASSEMBLY OUTPUT POWER: -11.1 dBm

RECEIVE POWER:(dBm) SYSTEM
LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	-24.8	-30.0
LBR	-25.3	-28.4
Bridge	-25.8	-27.5
Star	-17.6	-23.7

	CABLE	
Link	H.D.	L.D.
MCR-MCR	13.7	18.9
MCR-LBR	14.2	17.3
MCR-Bridge	14.7	16.4
MCR-Star	6.5	12.2

WAVELENGTH: 1300 nm

OPTICAL ASSEMBLY OUTPUT POWER: -18.6 dBm

RECEIVE POWER:(dBm) SYSTEM LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	-32.1	-36.2
LBR	-32.3	-36.3
Bridge	-31.8	-34.0
Star	-20.8	-26.8

	CABLE	
Link	H.D.	L.D.
MCR-MCR	13.5	17.6
MCR-LBR	13.7	17.7
MCR-Bridge	13.2	15.4
MCR-Star	2.2	8.2

OPTICAL POWER TEST REPORT

DATE: 25/03/86

OPERATORS: John Mayich

Mike Jerrett

TRANSMIT NODE: LBR

WAVELENGTH: 820 nm

OPTICAL ASSEMBLY OUTPUT POWER: -26.4 dBm

RECEIVE POWER:(dBm) SYSTEM
LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	-44.7	-44.7
LBR	-39.3	-41.2
Bridge	-46.4	-44.0
Star	-37.8	-40.2

	CABLE	
Link	H.D.	L.D.
LBR-MCR	18.3	18.3
LBR-LBR	12.9	14.8
LBR-Bridge	20.0	17.6
LBR-Star	11.4	13.8

WAVELENGTH: 1300 nm

OPTICAL ASSEMBLY OUTPUT POWER: -19.6 dBm

RECEIVE POWER:(dBm) SYSTEM LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	-36.4	-36.0
LBR	-33.0	-35.8
Bridge	-37.7	-35.8
Star	-29.9	-32.1

	CABLE	
Link	H.D.	L.D.
LBR-MCR	16.8	16.4
LBR-LBR	13.4	16.2
LBR-Bridge	18.1	16.2
LBR-Star	10.3	12.5

OPTICAL POWER TEST REPORT

DATE:09/01/87

OPERATORS: John Mayich

TRANSMIT NODE: MCR

WAVELENGTH: 820 nm

OPTICAL ASSEMBLY OUTPUT POWER: -12.3 dBm

RECEIVE POWER:(dBm) SYSTEM
LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	-29.7	-28.5
LBR	-30.3	-29.6
Bridge	-35.2	-27.6
Star	-24.0	-27.5

	CABLE	
Link	H.D.	L.D.
MCR-MCR	17.4	16.2
MCR-LBR	18.0	17.3
MCR-Bridge	14.9	15.3
MCR-Star	11.7	15.2

WAVELENGTH: 1300 nm

OPTICAL ASSEMBLY OUTPUT POWER: -20.0 dBm

RECEIVE POWER:(dBm) SYSTEM LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	-37.4	-36.7
LBR	-38.3	-36.1
Bridge	-39.7	-35.7
Star	-32.5	-35.3

	CABLE	
Link	H.D.	L.D.
MCR-MCR	17.4	16.7
MCR-LBR	18.3	15.7
MCR-Bridge	19.7	16.7
MCR-Star	12.5	15.3

OPTICAL POWER TEST REPORT

DATE:09/01/87

OPERATORS: John Mayich

TRANSMIT NODE: LBR

WAVELENGTH: 820 nm

OPTICAL ASSEMBLY OUTPUT POWER: N/R dBm

RECEIVE POWER:(dBm)

SYSTEM LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	–	–
LBR	–	–
Bridge	–	–
Star	–	–

	CABLE	
Link	H.D.	L.D.
LBR-MCR	–	–
LBR-LBR	–	–
LBR-Bridge	–	–
LBR-Star	–	–

WAVELENGTH: 1300 nm

OPTICAL ASSEMBLY OUTPUT POWER: N/R dBm

RECEIVE POWER:(dBm)

SYSTEM LOSS:(dB)

	CABLE	
Rx node	H.D.	L.D.
MCR	–	–
LBR	–	–
Bridge	–	–
Star	–	–

	CABLE	
Link	H.D.	L.D.
LBR-MCR	–	–
LBR-LBR	–	–
LBR-Bridge	–	–
LBR-Star	–	–

```
               OPTICAL POWER TEST REPORT

        DATE:09/01/87

   OPERATORS:  John Mayich


TRANSMIT NODE: bridge

   WAVELENGTH: 820       nm

OPTICAL ASSEMBLY OUTPUT POWER: -11.2     dBm


RECEIVE POWER:(dBm)                       SYSTEM
LOSS:(dB)
                CABLE                           CABLE

     Rx node  H.D.  L.D.               Link    H.D.  L.D.

        MCR -26.0  -22.1          bridge-MCR     14.8  10.9
        LBR -29.3  -24.9          bridge-LBR     18.1  13.7
     Bridge -24.1  -23.5          bridge-Bridge  12.9  12.3
       Star -21.5  -18.6          bridge-Star    10.3   7.4

   WAVELENGTH: 1300      nm

OPTICAL ASSEMBLY OUTPUT POWER: -29.4        dBm

RECEIVE POWER:(dBm)          SYSTEM LOSS:(dB)

                    CABLE                       CABLE

        Rx node  H.D.  L.D.            Link    H.D.  L.D.

        MCR   -41.7  -39.5        bridge-MCR     12.3  10.1
        LBR   -41.6  -40.4        bridge-LBR     12.2  11.0
     Bridge   -40.6  -40.7        bridge-Bridge  10.6  11.3
       Star   -39.0  -36.7        bridge-Star     9.6   7.3
```

Appendix D

Page

Post Cruise Visual Inspection D-2

Post Cruise Visual Inspection

Machinery Control Room (MCR) Mode

- Heavy duty star coupler enclosure
    - all splices in place
    - all hardware intact
    - one adhesive backed tie wrap hold down adrift. Bond broken between adhesive layer and nylon hold down
- Data highway
    - all hardware intact
    - all cards in place
    - connector on HD receive fibre 1 turn loose
    - one adhesive backed tie wrap hold down adrift. Bond broken between adhesive layer and nylon hold down.
- Light duty star coupler enclosure
    - all splices intact
    - all hardware intact

Lower boiler room (LBR) node

- all hardware intact
- all cards in place
- connector on HD receiver fiber 1 turn loose
- connector on radio Rx 1 turn loose
- "Tak Pack" adhesive holding pigtail exiting splice broken free of panel at transmitter end. Fiber slightly stressed.

Bridge node

- data highway
    - all hardware intact
    - all cards in place

Video monitor and Camera

- both camera and monitor securely in place
- the picture quality is good except when the camera is subjected to bright sunlight

Appendix E

CONNECTOR PREPARATION

Page

Fibre Cracking Problems Evident in 100/140 Graded Index Fibre E-2

Amphenol SMA Data Sheets E-5

OFTI SMA Data Sheets E-7

ofti Optical Fiber Technologies, Inc.

P.O. Box 119, Nutting Lake, MA 01865
5 Fortune Drive, Billerica, MA 01821
Tel (617) 663-6020 Telex 940-208

September 13, 1985
Page 1 of 2

FIBER CRACKING PROBLEMS EVIDENT IN 100/140 GRADED INDEX FIBER

100/140 graded index optical fibers were developed in the late 1970's-early 1980's in response to the datacom industries demand for low cost LED and photodiode devices. The 100/140 graded index fiber allowed for greater power coupling from the low cost electronic devices thereby increasing or preserving system performance at a lower system price. In addition to the larger core area presented by the 100/140 fibers, manufacturers strove to increase the numerical aperture (N.A.) and bandwidth of these fibers which made them more attractive to datacom users.

However, every technological advancement has its compromises. For the 100/140 graded index fiber, the compromise is terminatability. There is no doubt that whomever you speak to relating to the termination of 100/140 graded index fibers, the response will range from mildly negative to sheer panic! The problems encountered are: fiber cracks occuring during the use of elevated temperature curing epoxy as well as fiber pistoning due to an apparent poor bond strength of the epoxy to the fiber. Silca materials in the form of quartz or glass exhibit what is termed a low energy surface to which polar molecules similar to those of which epoxies are comprised have a difficult time bonding, except unique epoxy formulations which unfortunately require elevated temperature curing. Attempts have been made to use materials such as monofunctional silanes such as DOW Z-6040 to improve the bonding characteristics of low or room temperature curing epoxies. This method in our opinion has left inconclusive results as to the effectiveness of these materials. So, with regards to 100/140 fiber pistoning, which is a clearcut case of epoxy adhesive bonding, and elevated temperature cure material is highly recommended for best results.

However, a new problem occurs in that, due to the dopant characteristics of the core of 100/140 graded index fiber, which was chosen to increase the N.A. of the fiber, the fiber exhibits a high degree of sensitivity to elevated temperatures which manifests itself as fiber cracking. This cracking has also been noted to be termed "mercedes cracking" since more often than not the crack is in the shape of the Mercedes-Benz symbol.

Now, let's throw in an added variable, which would be the shrinkage of the epoxy upon curing which can exert compressive stress on the fiber. Also, exotic temperature cycling requirements by a customers application can further aggravate these situations.

The foregoing situations were, as we understand the prime motivation for major fiber producers to develope the 85/125 fibers which allow for large core coupling efficiency to economical LED sources, yet exhibit slightly lower N.A. conditions thereby reducing residual stress concentrations within the fiber core which is the case with 100/140 graded index products. There is no doubt that an engineering decision to use graded index fibers other than 100/140 would be a sound one in lieu of the years of problems with this product.

We might also note that 100/140 graded index fibers from various manufacturers exhibit varying degrees of the forementioned problems. It behooves the end user to be aware of these problems and evaluate adhesives and fibers for the best possible yield and performance if 100/140 fiber must be used.

order information

Connector Part Number	** Min. Fibre Hole Dia. (um)	Max. Buffer Dia. (mm) Min. Rearbody I/D	Max. Cable O.D. (mm) Min. I/D Ferrule	Comments	*** Compatible Cable
SMA (Stainless Steel)					
905-222-5000	251	2.51	4.42	Crimp	See NOTE IV
905-222-5001	439	2.51	4.42	Crimp	See NOTE XI
905-222-5002	657	2.54	4.42	Crimp	See NOTE X
906 SMA Style (Stainless Steel)					
906-109-5001	127	N/A	71	Epoxy *	See NOTE XIV
906-109-5002	127	N/A	1.70	Epoxy	*
906-109-5003	144	N/A	71	Epoxy	See NOTE XVII
906-109-5004	127	N/A	1.09	Epoxy	See NOTE XV
906-109-5005	144	N/A	1.09	Epoxy	See NOTE XVIII
906-110-4000	127	N/A	N/A	oval element construction	See NOTE XXII
906-110-5000	127	3.38	4.95	Crimp	*
906-110-5001	127	1.65	3.58	Crimp	*
906-110-5003	127	3.39	5.56	Crimp	*
906-110-5005	127	2.67	4.42	Crimp	See NOTE VI
906-110-5009	144	2.67	4.42	Crimp	See NOTE III
906-110-5012	144	3.78	5.56	Crimp	See NOTE XXIV
906-110-5013	203	1.65	3.58	Crimp	See NOTE IX
906-110-5014	127	3.96	5.72	Crimp	See NOTE XII
906-110-5015	157	1.65	3.81	Crimp	*
906-110-5016	144	1.65	3.59	Crimp	See NOTE V
906-110-5017	127	90	3.58	Crimp	See NOTE I
906-110-5018	144	90	3.59	Crimp	*
906-110-5019	127	1.59	4.42	Crimp	See NOTE VII
906-110-5020	144	1.09	4.95	Crimp	See NOTE II
906-110-5021	127	1.09	4.95	Crimp	See NOTE I
SMA (Stainless Steel) Coupling Nut with Safety Wire Hole					
906-110-6001	127	1.65	3.58	Crimp	*
906-110-6005	127	2.67	4.42	Crimp	See NOTE VI
906-110-6009	144	2.67	4.42	Crimp	See NOTE III
906-110-6013	203	1.65	3.58	Crimp	See NOTE IX
906-110-6014	127	3.96	5.72	Crimp	See NOTE XII
906-110-6015	157	1.65	3.81	Crimp	*
906-110-6016	144	1.65	3.58	Crimp	*
906 SMA Style (Stainless Steel)					
906-113-5000	251	2.67	4.42	Crimp	See NOTE XIII
906-113-5003	251	1.65	5.72	Crimp	See NOTE XIX
906-113-5006	251	3.38	5.72	Crimp	*
906-113-5008	251	1.09	4.95	Crimp	See NOTE IV
Hewlett Packard Compatible (Brass)					
906-120-5000	144	95	4.42	Crimp	See NOTE II
906-120-5001	127	95	4.42	Crimp	See NOTE I*
906-120-5002	251	1.09	4.42	Crimp	See NOTE IV
906-120-5003	144	2.49	4.42	Crimp	See NOTE III
SMA Style (Aluminum)					
906-121-5000	144	2.54	4.42	Crimp	See NOTE II, III, V
906-121-5003	251	2.51	4.42	Crimp	See NOTE IV
906-121-5004	129	2.54	4.42	Crimp	See NOTE I, VI, VII
SMA Style (Stainless Steel)					
906-122-5000	144	2.51	4.42	Crimp	See NOTE II, III, V
906-122-5003	251	2.51	4.42	Crimp	See NOTE IV
906-122-5004	129	2.54	4.42	Crimp	See NOTE I, VI, VII
SMA (Stainless Steel)					
906-123-5018******	144	1.65	3.58	Crimp	*
Miniature Bayonet Style (Stainless Steel)					
906-200-5000	144	2.51	4.42	Crimp	See NOTE II, III, V
906-200-5003	251	2.51	4.42	Crimp	See NOTE IV
906-200-5004	129	2.54	4.42	Crimp	See NOTE I, VI, VII
(Aluminum)					
906-200-7000	144	2.51	4.42	Crimp	See NOTE II, III, V
906-200-7003	251	2.51	4.42	Crimp	See NOTE IV
906-200-7004	129	2.51	4.42	Crimp	See NOTE I, VI, VII

*exception Remee construction not compatible

NOTE XII (125 um)
Siecor #112, #122, #212, #222, #612, #622, #172, #272, #012, #022
Valtec #MG05 40030 01

NOTE XIII (250 um)
Belden #220001*****

NOTE XIV (125 um)
ITT #T-1201 thru #T-1212

NOTE XV (125 um)
ITT #T-1221 thru #T-1232

NOTE XVI (1140 um)
Pirelli
Galite #1000 200T,
Galite #2000 200T,
Galite #1000 200P,
Galite #2000 200P

NOTE XVII (140 um)
ITT #T-1301, #T-1303, #T-1305, #T-1311, #T-1314

NOTE XVIII (140 um)
ITT #T-1302, #T-1304, #T-1306, #T-1312, #T-1314

NOTE XIX (245 um)
Pirelli

NOTE XX (350 um)
Belden #221001*****

NOTE XXI (250 um)
Times Fibre # LC Series

NOTE XXII (125 um)
Times Fibre # IH Series, AD Series, BH Series

NOTE XXIII (1000 um)
Eska SH4001; SH4002

NOTE XXIV (140 um)
Siecor #142, #242
Valtec #LC06 40030 01

NOTE XXV (600 um)
Valtec #PC10 40050 2
Remee A-252-01, A-262-01

* cable, connector was designed for is no longer in production

** fibre size refers to cladding diameter

*** 1mm buffer 3mm jacket O.D. is becoming a "defacto" cable jacketing standard. Other cable manufacturers who meet this "defacto" standard are compatible with our connectors. Those manufacturers listed in NOTE I & NOTE II were those known at the time of printing

**** due to the soft cladding of this plastic-clad silica fibre, an epoxy termination is not guaranteed

***** plastic clad silica, remove cladding, re-clad to terminate

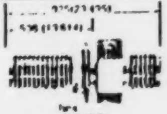
****** weathertight design

complementary products

adapters

for 905/906 fibre optic connectors with SMA-type threads

part number	description
905-120-5000	Bulkhead Feedthru, D-Hole, Jack-Jack
905-120-5003	In-Line, Jack-Jack
905-120-5004	Half Length
905-120-5008	Environmentally Sealed, Bulkhead Feedthru, D-Hole Mount, Jack-Jack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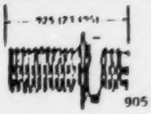
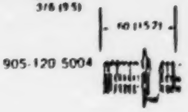
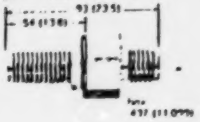
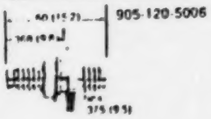

905-120-5003
.925 (23.495)

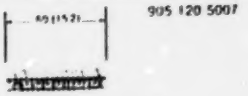

905-120-5004
.60 (15.2)


905-120-5008
.93 (23.5)
.54 (13.8)

for miniature 906 fibre optic connectors with SMC-type threads (Hewlett-Packard compatible)

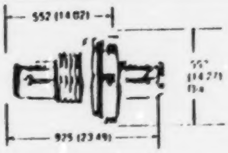
part number	description
905-120-5006	Bulkhead, Jack-Jack
905-120-5007	In-Line, Jack-Jack


905-120-5006
.60 (15.2)
.375 (9.5)


905-120-5007
.60 (15.2)

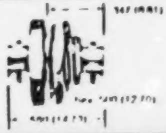
for 905/906 miniature bayonet fibre optic connectors

part number	description
905-201-5000	Bulkhead Feedthru, D-Hole Mount, Jack-Jack


905-201-5000
.552 (14.02)
.925 (23.49)

for 905/906 micro bayonet fibre optic connectors (National Semi-conductor compatible)

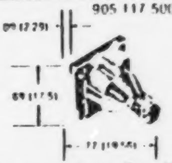
part number	description
905-144-5000	Bulkhead Feedthru, Jack-Jack


905-144-5000

receptacles

for 905/906 fibre optic connectors with SMA-type threads

part number	description
905-117-5000	Flange Mounted, TO-5*
905-118-5000	P.C. Screw Mount, TO-5*
905-131-5000	P.C. Solder Mount, TO-5*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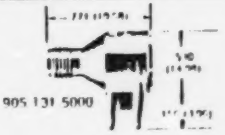
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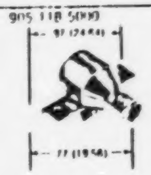
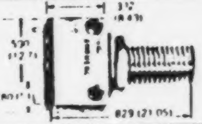
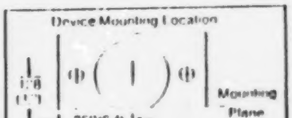

905-118-5000

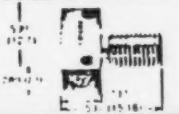
*Note: To convert to sizes other than TO-5, refer to accessories—receptacles, Page 19

part number	description
905-135-5000	P.C. Mount, Low Profile, FOAC, with R.F. Shield Backplate
905-135-5001	P.C. Mount, Low Profile, FOAC
905-135-5002	P.C. Mount, Low Profile, FOAC, Plastic Backplate


905-135-5000
.829 (21.05)


Device Mounting Location
.250 (6.4)
Mounting Plane

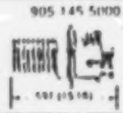
part number	description
905-138-5001	P.C. Mount, Low Profile, TO-18/TO-46, Plastic & Metal Sweetspot™
905-138-5002	P.C. Mount & Bulkhead Hex Mount, Low Profile, TO-18/TO-46, Plastic & Metal Sweetspot™

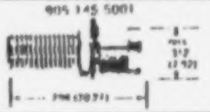

905-138-5001

complementary products

receptacles cont'd

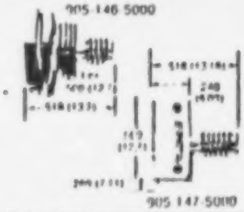
for 905/906 SMA-type threads cont'd

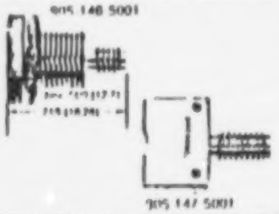




part number	description
905-145-5000	Bulkhead, Hex Mount, TO 18/TO-46, Plastic & Metal Sweetspot
905-145-5001	Bulkhead, Hex Mount, FOAC

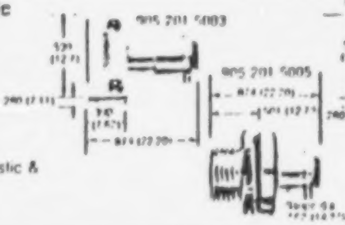
for miniature 906 fibre optic connectors with SMC-type threads (Hewlett-Packard compatible)

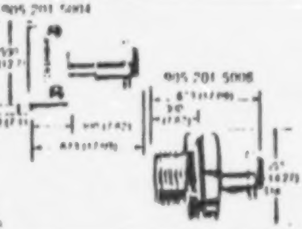




part number	description
905-146-5000	Bulkhead Mount TO 18/TO 46, Plastic & Metal Sweetspot
905-146-5001	Bulkhead Mount FOAC
905-147-5000	P.C. Mount, Low profile, TO-18/TO 46, Plastic & Metal Sweetspot
905-147-5001	P.C. Mount, Low Profile, FOAC

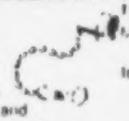
for 905/906 miniature bayonet fibre optic connectors

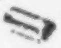




part number	description
905-201-5003	P.C. Mount, FOAC Receptacle, No Backplate
905-201-5004	P.C. Mount TO 18/TO 46, Plastic Sweetspot
905-201-5005	Bulkhead Mount FOAC Receptacle
905-201-5006	Bulkhead Mount TO 18/TO 46, Plastic & Metal Sweetspot

accessories





part number	description
905-163	Metal Dust Cap for 905/906 Threaded SMA Receptacles
906-101-3001	Full Length Delrin Sleeve to be used in Conjunction with Two 906 Connectors and One Adapter
906-101-3002	Half Length Delrin Sleeve to be used in Conjunction with One 906 Connector and One Receptacle

receptacle inserts

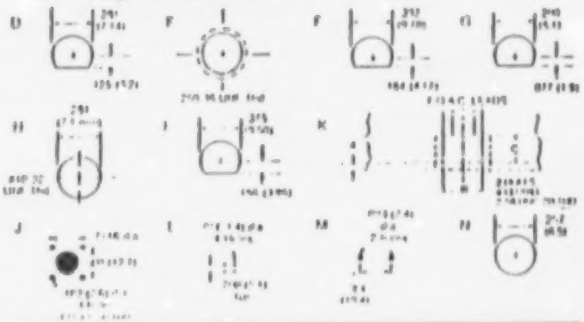
Metal Inserts to Convert TO-5 Devices
905 117 5000, 905-118-5000, 905 131 5000
to Different Sizes

For TO 46 Device	No 905 5008 1
For RCA 2002A	No 905 5008 10
For H P 5082 4720 Device	No 905 5008 2
For Honeywell LED Device	No 905 5008 4
For Motorola MRD 300 Device	No 905 5008 3
For Motorola MRD 510 Device	No 905 5008 6
Single Pilot Hole .040" (1.016) dia	No 905 5008 5
Blank	No 905 5008-7
TO-18/TO 72	No 905 5008 13
209 12	No 905 5008 12

Part No.	A	B	C	Figure
905 135 5000	125(3.17)	375(9.52)	256(6.5)	K,E
905 135 5001	125(3.17)	375(9.52)	256(6.5)	K
905 135 5002	125(3.17)	375(9.52)	256(6.5)	K,E
905 138 5001	125(3.17)	375(9.52)	155(3.74)	K
905 138 5002	125(3.17)	375(9.52)	155(3.74)	K,E
905 147 5000	125(3.17)	375(9.52)	165(4.19)	K
905 147 5001	125(3.17)	375(9.52)	295(7.49)	K
905 201 5003	125(3.17)	375(9.52)	225(5.71)	K
905 201 5004	125(3.17)	375(9.52)	225(5.71)	K

Part No.	Figure	Part No.	Figure
905 117 5000	J	905 131 5000	L
905 118 5000	G	905 144 5000	I
905 120 5000	D	905 115 5000	H
905 120 5003	F	905 145 5001	H
905 120 5004	I	905 146 5000	H
905 120 5006	G	905 146 5001	I
905 120 5007	H	905 201 5000	I
905 120 5008	D	905 201 5005	I

mounting dimensions



SMA-EPOXY STYLE
SINGLE CHANNEL, Single Fiber, FO CONNECTORS
ALL METAL

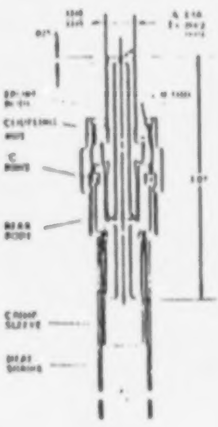
Optical Fiber Technologies Inc

SERIES
200
(Stainless Steel)

Intermateable
with MIL standard*
SMA "905" type

Actual Size

Features a loss of less than 2dB per splice.[1] Appropriate for fibers ranging from 125 to 1981 micron diameters, buffer diameters to .125" (3.1mm) and cable diameters to .210" (5.3mm).



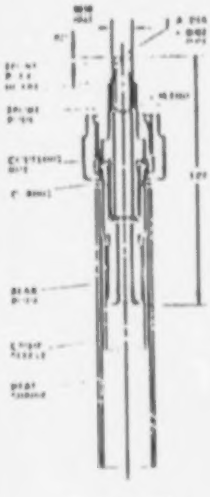
Finished ferrule length

SERIES
200-S
(Stainless Steel)

Intermateable
with MIL standard*
SMA "906" type.

Actual Size

Features a loss of less than 2dB per splice.[1] Appropriate for fibers ranging from 125 to 1143 micron diameters, buffer diameters to .125" (3.1mm) and cable diameters to .210" (5.3mm).



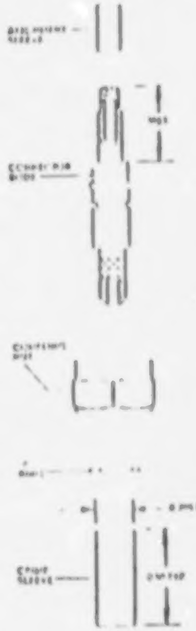
Finished ferrule length

SERIES
200-SA
(Alumunium)

Intermateable
with MIL standard*
SMA "906" type.

Actual Size

Aluminum front body means lower cost and lighter weight. Features a loss of less than 2dB per splice.[1] Same fiber and cable compatibility as Series 200 S.



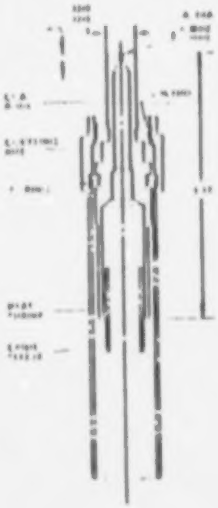
EXPLODED VIEW

SERIES
200-CCAD
(Nickel Plated Zinc Die Cast)

Intermateable
with MIL standard*
SMA "905" type

Actual Size

Features a loss of less than 2dB per splice.[1] Appropriate for fibers ranging from 125 to 1981 micron and buffer diameters to .040 (1mm) and cable diameters to .125 (3.1mm) Nickel Plated Zinc Die Cast construction means lower cost and lighter weight



Finished ferrule length

RECEPTACLE
For all the above use the OFTI SMA PCR 001 or PCR 002 P.C. Mount/Bulkhead Receptacle

SPLICE BUSHINGS
Use the OFTI
2205 Splice Bushing

(See Separate Auxiliary Hardware Data Sheet)

*NOTE: Dimensions conform to MIL-C-83522/1A/2A

SMA CERAMIC SERIES: CONSULT SEPARATE DATA SHEET

---

[1] Loss measurements are based upon a long short test method where steady state modal conditions are achieved in the launch fiber. Loss measurement data is based on 50 x 125μ fibers with an NA of .20 minimum

Epoxy Style SMA FO Connectors
MECHANICAL and PERFORMANCE SPECIFICATIONS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*For mated connector pair

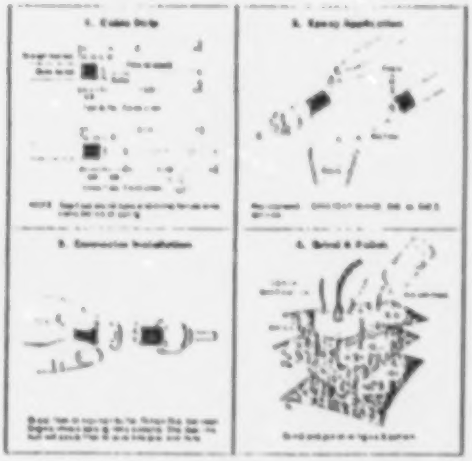
Note: Additional [illegible] are available. Consult OFTI for quotation and availability.

Suggested Termination Procedures for OFTI SMA Epoxy Style Fiber Optic Connectors

1. [illegible]
2. Strip cable using diagram 1 [illegible]
3. [illegible]
4. Mix a small amount of epoxy in accordance with the manufacturers instructions. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]
8. [illegible]
9. [illegible]
10. [illegible]
11. [illegible]

[illegible]

12. [illegible]



Termination Instructions for the OFTI 300-CCAD Connector

1. [illegible]
2. [illegible]
3. Add epoxy to connector
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]
8. Cure epoxy
9. Heat shrink tubing
10. Grind and polish as usual

All tools and materials [illegible] are stocked by OFTI.

[illegible]

For complete termination [illegible] and Techniques [illegible] available from OFTI.

[illegible]

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[illegible]

Optical Fiber Technologies, Inc.

THE FO CONNECTOR SPECIALISTS

P.O. Box 140, Hutting Lake, MA 01085 Tel: (617) 603 0020 Telex: 940 200

Focal Marine Limited
Electro-optical Engineers

CA1
DTC 800
87
D27
v.2
c.2

TP8469E

DEVELOPMENT AND TESTING OF A FIBRE OPTIC DATA SYSTEM FOR MARINE TRANSPORTATION

VOLUME II: PROPOSED STANDARDS

by

G.A.J. Smith
J.W. Snow
J.S. Mayich
FOCAL MARINE LIMITED

April 1987

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Prepared for
Transportation Development Centre

DISCLAIMER

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Un rapport sommaire de ce document est disponible en français.

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17. Abstract

The purpose of this project was to draft standards for the shipboard use of fibre optics. To gain the necessary experience, a pilot data and video system was designed and installed on an icebreaker.

The method of measuring system performance was through digital bit error rate, optical power and video quality. Power and reflectometer checks before and after sea trials also served to show environmental dependencies.

The results showed no correlation between optical performance and environmental parameters (high and low temperatures, vibrations) or cable type. Certain weaknesses were highlighted in component design and selection.

In conclusion, the fibre optic system performed well. A set of draft standards was produced which can serve as a guide to allow marine shipping interests to take full advantage of the benefits of this technology.

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16. Agent de projet — CDT
Micha Avni

17. Resumé

L'objectif de cette recherche a été de définir des normes concernant les utilisations marines des câbles à fibres optiques. Afin d'acquérir l'expérience nécessaire, un système pilote de transmission de données vidéo-alphanumériques a été conçu, réalisé et installé à bord d'un brise-glace.

La méthode de mesurage des performances a été triple: taux d'erreurs dans la transmission des données numériques, puissance optique à la réception et qualité de la visualisation. Des contrôles de puissance et de réflectivité ont été faits avant et après les essais en mer, aux fins de mettre en évidence l'influence des facteurs d'environnement.

Les résultats ne dégagent aucune corrélation entre paramètres optiques et paramètres d'environnement: écarts de température, niveaux vibratoires, pas plus qu'entre différents types de câbles. Certaines faiblesses ont été mises en évidence au niveau de la conception et de la sélection des composants.

L'appareillage à fibres optiques a bien fonctionné. Un ensemble de normes provisoires a été rédigé; il pourra servir de guide aux transporteurs maritimes souhaitant tirer parti de cette technologie.

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DRAFT

PROPOSED STANDARD
FOR THE SHIPBOARD USE OF
OPTICAL FIBRE CABLE

NOTICE

This proposed Standard is designed to help eliminate misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining, with minimum delay the proper product for his particular need. However, the existence of this Standard for shipboard use of optical fibre cables does not preclude the use of products not conforming to the standard.

The Standard is recommended without regard to patents or other proprietary rights. No liability is assumed in regard to such rights, nor is there any obligation to parties adopting the Standard.

FOCAL MARINE LIMITED
1378 Bedford Highway
Bedford, Nova Scotia

April, 1985
Updated February, 1987

PROPOSED STANDARD
FOR THE SHIPBOARD USE OF
OPTICAL FIBRE CABLE

1.0 Scope

This Proposed Standard provides guidelines for the construction, selection and testing of fibre optic cables intended for shipboard use.

The standard is proposed in the interest of uniformity and hence does not address special methods for extreme conditions.

The test procedures are based primarily on EIA-455, "Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Connecting and Terminating Devices." This applies to fibre optic cable in general and is adopted as part of this Proposed Standard except where modification is needed to conform to shipboard use. Where such modification is needed, the proposed content is provided (see section 4.3).

2.0 Applicable Documents

EIA-455
DOD-C-85045
DOD-STD-1678

3.0 Requirements for Shipboard Fibre Optic Cables

3.1 Classification of Type

Fibre optic cables are classified as follows:

- single fibre
- multifibre
- fibre bundle
- hybrid (containing fibre and electrical elements)

The classification according to fibre type is given in the Proposed Standard for the Shipboard Use of Optical Fibre Waveguide which addresses fibre construction (refractive index profile) and the preferred fibre type for shipboard use.

3.2 Material

3.2.1 Fibre Material

The classification of fibre materials is addressed in the Proposed Standard for Shipboard Use of Optical Fibre Waveguide.

3.2.2 Jacket and Buffer Material

The jacket and buffer materials are required to meet the specifications identified for the particular application.

Common buffer materials, for application directly to the clad, are acrylate and silicone.

General considerations associated with jacket material selection are given in Table 1 for polyvinyl chloride (PVC), high-density polyethylene (HDPE), polyurethane (PU) and polytetrafluorethylene (PTFE) or Teflon.

Both HDPE and PU have major attractions for shipboard use, the drawbacks being stiffness and high friction coefficient respectively. Teflon is the best at high temperatures.

TABLE 1
COMPARISON OF JACKET MATERIALS FOR FIBRE OPTIC CABLE

MATERIALS	TYPICAL APPLICATIONS	ADVANTAGES	DISADVANTAGES
PVC	-INDOOR DUCTS, TRAYS	-INEXPENSIVE -FLEXIBLE -EASY TO REMOVE -AVAILABLE	-POOR RESISTANCE TO SUNLIGHT, FLAME PROPAGATION, ABRASION AND CUTS, RADIATION -FUME PROPAGATION
HDPE	-OUTDOOR -UNDERWATER -UNDERGROUND -MULTIFIBRE CABLES	-INEXPENSIVE -RESISTANT TO SUNLIGHT, MOISTURE DIFFUSION, CUTS, CRUSHING	-STIFF -POOR RESISTANCE TO FLAME
PU	-SANDY ENVIRONMENTS -WINCHES -MILITARY FIELD USE -IONIZING RADIATION (NUCLEAR PLANTS, SPACECRAFT)	-FLEXIBLE -RESISTANT TO UV, ABRASIONS & CUTS -FLAME RETARDANT FORMULATIONS AVAILABLE	-MORE EXPENSIVE -HIGH FRICTION
PTFE	-HIGH TEMP. (150C) -IONIZING (NUCLEAR, SPACECRAFT)	-TEMPERATURE RESISTANT -RADIATION RESISTANT -LITTLE SMOKE/ FUME PROPAGATION	-EXPENSIVE -EASILY CUT -STIFF

3.3 Cable Construction

3.3.1 Fibres

Fibres shall be dimensionally uniform, free of lumps, splits or abraded surfaces and inclusions.

3.3.1.1 Splices

The number of splices shall be no more than 2 per kilometer, and there shall be no splices which increase the fibre diameter by more than 5% or which adversely affect the physical or optical properties.

3.3.1.2 Size Measurement

When measured in accordance with EIA-455 procedures the following parameters shall meet the requirement of the particular specification.

(a) OD of graded index (GRIN) fibre EIA-455-27

(b) core and clad diameters of step index (SI) fibres EIA-455-45

(c) concentricity of core and clad EIA-455-45

(d) ovality of core and of clad EIA-455-45.

3.3.2 Attenuation

When measured in accordance with EIA-455-95 the attenuation of the fibre in the cabled state shall not exceed the requirements of the particular specification. As a guideline the attenuation of the cabled fibre shall not increase by more than 0.5 dB/km over the attenuation of the uncabled fibre.

3.3.3 Construction Types

3.3.3.1 Tight Buffer

In this type of cable the buffer material is applied directly to the clad, usually in more than one layer. The strength member and jacket are then applied. The result is a cable with minimal diameter and good handling properties. The drawbacks are limited tensile capability and proneness to localized "microbending" which could be induced by ice formation or non-uniformity in materials.

3.3.3.2 Loose-Tube

In this construction each fibre resides in a loose tube which itself is crush resistant. The benefit is higher tensile capability due to the facility to elongate, and freedom from microbending and associated attenuation. However diameter is greater and handling is more difficult (larger bend radius). When loose tube constructed cable is used, the tubes can be gel filled to prevent vibration of the fibre within the tube, for water blocking and to support the fibre in vertical runs (see para 3.3.4.4). No more than one fibre should be fitted in a tube.

3.3.4 Finished Cable

The finished cable shall meet the requirements of the particular specification in regard to design, construction, outside diameter and other physical dimensions, such as concentricity, colour and marking.

3.3.4.1 Jacket and Buffer

The jacket and buffer shall be mechanically removeable to allow for proper termination and splicing techniques to be employed.

3.3.4.2 Strength Member

The normal materials for strength members are polyarylamide (aramid), carbon fibres and metal strands. Aramid material is generally favoured for shipboard use in view of its high strength to weight ratio.

3.3.4.3 External Braid

External braid of the basket-weave type using either bronze or stainless steel strands may be used in marine applications as required. It is not required for electromagnetic interference (EMI) protection, due to the dielectric nature of optical fibre, nor for heat dissipation.

3.3.4.4 Moisture Barrier

The following methods are used to protect optical fibre against moisture penetration (which can accelerate degradation due to static fatigue cracking caused by hydroxyl ion attack):

(a) metal sheath
(b) water-blocking gel
(c) ceramic coated fibre

The best configuration of metal sheath is a seam-welded construction; a helical wrap slows but does not prevent moisture penetration.

Gel is sometimes used within a loose-tube construction. Where waterblocking gel is used, the gel shall be inert and easily removed from the fibre without the use of chemicals or special mechanical devices. The consistency of the gel shall remain stable over the entire operational and storage temperature range of the cable. In this regard, the cable shall be tested in accordance with EIA-455-81.

Ceramic coatings provide a hermetical seal when applied directly to the fibre cladding.

3.3.4.5 Fillers

Fillers can be used to contribute to the cable construction for the purpose of developing the cable shape, firmness and stiffness. When used, fillers shall be inert, non abrasive and non-hygroscopic.

4.0 Cable Test Procedures

4.1 Standard Conditions

Unless specified by the individual design standard or test procedure, all measurements shall be made when conditions are as follows: .

(a) Temperature 25 C +/- 5 C
(b) Barometric Pressure 90-105 kPa
(c) Relative Humidity 30-60%

4.2 Adopted Test Procedures

Following are the test procedures called up by EIA-455 which are considered suitable unchanged for use with shipboard fibre optic cable:

EIA-455 1. 2, 3, 6. 7*, 8*, 9, 11, 13, 14, 16, 17, 18,
20, 21, 22, 23, 25, 26, 32, 33, 36, 37, 39,
40, 41, 42, 49, 50, 53*, 54, 57*, 59A*, 59B*,
60*, 61*, 62*, 67*, 68*, 69*, 70*, 71*, 72*,
73*, 74*, 75*, 77*, 78*, 81. 82, 83, 84, 85,
86, 87, 88*, 89, 91*, 94*, 95*, 96*, 97*, 98,
99, 100, 101, 102*, 103, 104*, 107*, 109*,
118*, 160*, 161*, 162*, 163*, 164*, 171*.

Entries marked * are presently in process of preparation by EIA but are expected to be suitable unchanged for shipboard use.

4.3 Modified Test Procedures

Some of the test procedures are based on the EIA recommended procedures but need to be modified for shipboard use. A list of titles plus a short description of the intent of the modification follows:

EIA-455-3	Temperature Cycling (Thermal Shock): Temperature ranges occurring onboard vessels are to be specified, both for predominantly warm locations (like boiler rooms) and cold locations (outdoors). A proposed Table 1 is attached.
EIA-455-26	Crush Resistance: Conditions onboard vessels are to be more accurately simulated.
EIA-455-40	Fluid Immersion Test for Fibre Optic Cable: Fluids common onboard vessels are to be specified. A proposed Table 1 is attached, adding gasoline, diesel fuel, anti-icing fluid and mineral spirit.

4.3.1 Temperature Cycles

One cycle consists of steps 1 through 3 of the applicable test condition. Specimens shall not be subjected to forced circulating air while being transferred from one chamber to another. Direct heat conduction to the specimen should be minimized.

4.3.2 Exposure Time at Temperature Extremes

The cable samples shall be subjected to the temperature extremes for one of the durations of Table 2. The duration of the test and length of exposure are standardized for a given mass of the test item. This approach allows the cable to reach thermal stability at the temperature of the test chamber while keeping the testing time to a minimum.

Table 1 to EIA-455-3

Temperature Cycling

	Test Condition	Number of Cycles
Step	A	5
	A-1	25
	A-2	50
	A-3	100
	Temperature (degrees C)	Time (Minutes)
	Hot Cycle	Cold Cycle
1	20 degrees C	20 degrees C
2	150 degrees C	-50 degrees C
3	20 degrees C	20 degrees C

Table 1 to EIA-455-40

Immersion Test Fluids

Test Fluids	Test Temp. Deg. C	Immersion Period Hours
Lubricating Oil, Synthetic Base	48-50	20
Hydraulic Fluid, Petroleum Base	48-50	20
Isopropyl Alcohol	20-25	168
Turbine Fuel, Aviation	20-25	168
H_2O (Water)	20-25	20
Salt Solution (5% by weight)	20-25	20
Methyl Isobutyl Ketone	20-25	168
Alkaline Water Base	63-68	20
Gasoline	20-25	168
Diesel Fuel	20-25	168
Trichlorethane	20-25	168
Anti-Icing Fluid	20-25	168
Methylene Chloride	20-25	168
Mineral Spirits	20-25	168
Freon	20-25	46

5.0 Documentation

Test data sheets should contain the following:

5.1 Data and title of test.

5.2 Identification of fiber optic cable tested, together with any other applicable data.

5.3 Test equipment used and date of calibration (if applicable).

5.4 Identification of the test method or procedure used (EIA-455-40 or other).

5.5 Test conditions (fluid investigated, conditioning time and temperature).

DRAFT

PROPOSED STANDARD
FOR THE SHIPBOARD USE OF
OPTICAL FIBRE WAVEGUIDE

NOTICE

This proposed standard is designed to help eliminate misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. However the existence of this standard for shipboard use of optical fibre does not preclude the use of products not conforming to the standard.

The standard is recommended without regard to patents or other proprietary rights. No liability is assumed in regard to such rights, nor is there any obligation to parties adopting the standard.

DRAFT

PROPOSED STANDARD
FOR THE SHIPBOARD USE OF
OPTICAL FIBRE WAVEGUIDE

Introduction

The development and shipboard use of optical waveguide communication systems and the associated components such as cables, connectors, couplers, light sources and detectors will be facilitated if waveguide fibre types are standardized, and if the number of such standard fibre types is minimized. The selection of fibre numerical aperture (NA) and core and cladding diameters is governed by a number of factors that impact system performance, reliability and cost. The most important of these factors are connector and splice insertion loss, source-to-fibre coupling loss, microbend resistance, and minimum permissible fibre (or cable) bend radius.

Applicable Documents

EIA-458-A
EIA-440
EIA-455

1.0 Scope

1.1 Intent

1.1.1 This Proposed Standard specifies optical fibre waveguide core and clad material classes, plus preferred sizes, for shipboard optical communication applications.

1.1.2 This Proposed Standard is based on EIA-458-A "Standard Optical Waveguide Fiber Material Classes and Preferred Sizes," (June, 1984).

1.2 General Material Description

1.2.1 The core material of a fibre waveguide is surrounded by a clad material of lower index of refraction. The core and clad materials constitute the light-guiding structure of a fibre waveguide and are the subject of this Proposed Standard.

1.2.2 Other materials may jacket the cladding to provide a number of desirable characteristics such as physical protection, increased product strength. or isolation from external mechanical forces. Jacketing material classes will be specified separately in the proposed standard for shipboard use of fibre optic cables.

1.3 Some Applications (refer Table I)

1.3.1 Material Class Ia fibres are suitable for long distance, repeaterless spans where a small number of rematable connectors (as opposed to permanent splices) are required, or for short distance spans where a large number of connectors and a wide bandwidth are required. Examples of long distance applications include telephone, CATV, rail, rapid transit and electric power grid communications systems. Examples of short distance applications include computer channel links and local area networks. All foreseeable shipboard applications are in the short range category.

A high bandwidth-distance product is desired in all of these applications, but is most critical in the long distance applications, where fibre attenuation accounts for the majority of the system loss budget and where data rates are high. In the short distance applications, however, the source-to-fibre coupling loss and the connector loss are the majority of the system loss budget.

1.3.2 Material (shipboard): Classes I and II are well suited for communications applications where short span distances are involved and bandwidth requirements are low.. Examples of such applications include computer data links, machinery control and communication systems.

2.0 Definitions

Proposed definitions needed for the technical understanding of this proposed standard are found in EIA-440, "Fibre Optic Connector Terminology" (May. 1978).

3.0 Material Classes

Standard waveguide fibre material classes are listed in Table I.

Table I

Optical Waveguide Fibre Material Class Standards

General Type	Class	Index	Profile Parameter (Note a)	Core Material (Note b)	Cladding Material (Note b)
Multi-mode	Ia	graded	3>g>1	glass	glass
	Ib	Quasi-step	10>g>3	glass	glass
	Ic	step	g>10	glass	glass
	II	step	g>10	glass	plastic
	III	step	g>10	plastic	plastic
Single-mode	IV	step	g>10	glass	glass

Notes:

a. the symbol "a" has been used in the past to refer to the profile parameter, but in the interest of international standardization, "g" is now being used, while "a" is being used for attenuation rate.

b. the term "glass" refers to a material which usually consists of metallic oxides. It includes the term "silica".

4.0 Standard Sizes

The current standard sizes of optical fibres are listed in Table II for Material Classes I and II. Other sizes for these classes may be added later. Standard sizes for Classes III and IV will be added later, as there is presently a diversity of sizes available.

Table II

Standard Sizes of Optical Waveguide Fibres

Material Class I (Glass Core, Glass Clad)

Core Diameter um	Outside (Clad) Diameter, um	Nominal Numerical Aperture (NA)
50	125	0.19 to 0.25
62.5	125	0.27 to 0.31
85	125	0.25 to 0.30
100	140	0.25 to 0.30

Material Class II (Glass Core, Plastic Clad)

Core Diameter um	Outside (Clad) Diameter, um	Numerical Aperture (NA)
200	to be specified	to be specified
400	to be specified	to be specified

Note: All diameter tolerances shall be called out in the applicable Detail Specification.

5.0 Preferred Types for Shipboard Use

5.1 Size

The preferred size for shipboard use is 100/140 um. This fibre, being of reasonably large diameter, permits good coupling of light into the fibre and easy connecting.

The other Class I sizes are also suitable for marine use. Coupling is not as easy as with 100/140 but the 125 um clad diameter has become more of a standard, enhancing component and fibre availability.

5.2 Class

The preferred class of fibre for marine use is glass core, glass clad, graded index (Ia in Table 1). These choices of material and index profile minimize the attenuation and dispersion respectively, optimizing the bandwidth-distance product.

6.0 Testing Methods

Testing of waveguide for use in shipboard fibre optic cables is no different than that required for other cable applications. Reference is made to EIA-455.

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PROPOSED STANDARD FOR THE SHIPBOARD INSTALLATION OF FIBRE OPTIC CABLE

NOTICE

This proposed standard is designed to help eliminate misunderstandings between manufacturers of products, and assist the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. However the existence of this standard for the marine installation of optical fibre cables does not preclude the use of methods not conforming to the Standard.

The Standard is recommended without regard to patents or other proprietary rights. No liability is assumed in regard to such rights nor is there any obligation to parties adopting the standard.

FOCAL MARINE LIMITED
1378 Bedford Highway
Bedford, Nova Scotia

April, 1985.
Updated February. 1987.

Purpose

This Proposed Standard for shipboard cable installation is recommended for the installation of fibre optic cable in Canadian merchant vessels. It is not intended to supercede existing standards for the installation of cables aboard such vessels but rather to supplement existing standards.

Applicable Documents

TP 127E	Ship Safety Electrical Standards
EIA 455-13	Visual and Mechanical Inspection of Fibres, Cables, Connectors and/or Other Fibre Optic Devices
EIA 455-33	Fibre Optic Cable Tensile Loading and Bending Test
EIA 455-37	Fiber Optic Cable Bend Test Low and High Temperature
EIA 455-89	Fibre Optic Cable Jacket Elongation and Tensile Strength
EIA 455-96	Fibre Optic Cable Storage Temperature Test
IEEE STD 45-1983	IEEE Recommended Practice for Electric Installations on Shipboard
CCG DGTE-69(E)	General Specification for the Installation of Shipboard Electronic Equipment
EIA-455-81	Compound Flow (Drip) Test for Filled Fibre Optic Cable
EIA-455-82	IP (In Preparation)
EIA-455-83	Cable to Interconnecting Device Axial Compressive Loading
EIA-455-84	Jacket Self-Adhesion (Blocking) Test for Fibre Optic Cable
EIA-455-85	Fibre Optic Cable Twist Test
EIA-455-86	Fibre Optic Cable Jacket Shrinkage
EIA-455-87	Fibre Optic Cable Knot Test
EIA-455-88	
EIA-455-89	Fibre Optic Cable Jacket Elongation and Tensile Strength
EIA-455-91	Fibre Optic Cable Twist-Bend Test
EIA-455-94	IP
EIA-455-95	Absolute Optical Power Test for Optical Fibres and Cables
EIA-455-97	IP
EIA-455-98	IP
EIA-455-99	Gas Flame Test for Special Purpose Fibre Optic Cable

IA-455-100	Gas Leakage Test for Gas-Blocked Fibre Optic Cables
EIA-455-104	IP
EIA-455-160	IP
EIA-455-161	IP
EIA-455-162	IP
EIA-455-163	IP
EIA-455-171	IP
EIA-455-172	Flame Resistance of Firewall Connector

1.0 Compatibility with Electrical Practice

1.1 Some aspects of the Transport Canada publication TP 127E, Ship Safety Electrical Standards, apply equally well to electrical and fibre optic installations. From Section 13, Installation of Cables, these sections are listed in Table 1.

Publication	Section	Paragraph
TP 127E	13	1,5,6,8,9,10,11,12,15,19,20, 23,24,25,26,27,28,29,30,31,33, 38

Aspects of TP 127E Which Apply, Unchanged, to the Installation of Fibre Optic Cable

Table 1

1.2 There are some aspects of TP 127E which can be applied to the installation of fibre optic cables with some changes. These changes are noted in section 2 of this Proposed Standard and the aspects affected are listed in Table 2.

Publication	Section	Paragraph
TP 127E	13	7,18,21

Aspects of TP 127E Which Apply With Modification to the Installation of Fibre Optic Cables

Table 2

1.3 Some aspects of TP 127E do not apply to the installation of fibre optic cables. These aspects are listed in Table 3.

Publication	Section	Paragraph
TP 127E	13	2,3.4,13,14,16,17,22.32,34, 35,36,37

Aspects of TP 127E Which Do Not Apply to the Installation of Fibre Optic Cable

Table 3

2.0 Amendments to Section 13 of TP 127E for Fibre Optic Cable Applications

2.1 Amendment to 13(7)

In machinery spaces and refrigerated spaces, or in wet or damp locations, cables shall, unless run in steel conduit or steel pipe, be PU (polyurethane) or PVC (polyvinyl chloride) sheathed, with or without braid.

2.2 Amendment to 13(18)

Where a fibre optic cable is bent, the internal radius of the bend shall be not less than the appropriate value set forth in section 4.1.5 or 5.4 of the proposed standard for the marine installation of fibre optic cables.

2.3 Amendment to 13(21)

2.3.1 Joints in all optical fibres shall be mechanically and optically secure and made only in junction or outlet boxes. Enclosures located outboard shall be weathertight.

2.3.2 This requirement does not apply to repairs made to fibres which have been damaged while in service. In that case fibres can be reconnected with a mechanical or fusion splice. Such spliced fibres must be protected in such a manner that the protection provided is, at the minimum, equal to that provided by the original cable. The protection provided must be continuous from the intact portions of the cable over the entire splice area and must remain so under normal operating conditions.

2.3.3 Where it is not possible to provide the degree of protection given in 2.3.2, the damaged section of cable should be replaced in whole or in part. If a part of the cable is replaced, it should be connected to the remaining cable in accordance with 2.3.1 or 2.3.2.

3.0 Fibre Optic Cable Inspection

3.1 The purpose of these inspections is to ensure that the integrity of the cable has been maintained during the installation procedure.

3.2 Preinstallation Inspection

3.2.1 Prior to installation each fibre in the cable shall be inspected for continuity. This should be done in accordance with EIA-455-53, 59B, 60 or 95.

3.2.2 The attenuation, at one of the designed wavelengths, should be measured and recorded for each fibre individually. If, in a multifibre cable, the fibres are identifiable, the attenuation should be identified for each fibre. The fibre attenuation while on the spool may be higher than that specified for the cable. These measurements are only intended as a guide in determining the integrity of the cable.

If the length of cable to be installed can be removed from the spool and laid out in a straight line or faked out with very large bends, then the attenuation measurement can be taken to be the true value for the length of cable. The cable can be accepted or rejected based on the results of these measurements.

3.2.3 All internal and/or external metallic elements should be tested for continuity.

3.3 Installation Inspection

3.3.1 During the installation process the cable should be visually inspected for damage to the external surfaces.

3.3.2 The length of cable installed should be measured as the cable is reeled out for the purpose of providing data to be used in later testing (see 3.4.3).

3.4 Post Installation Inspection

3.4.1 Following the inspection of a length of cable, internal metallic components should be tested for continuity.

3.4.2 Each fibre should be tested for continuity as in 3.2.1.

3.4.3 The optical attenuation tests conducted in 3.2.2 should be repeated. These measurements should be in line with values calculated using the measured length of cable and the specified loss per unit length according to the formula:

$$\text{measured loss} < (\text{measured length} \times \text{specified loss per unit length}) + 15\%.$$

4.0 Cable Data

4.1 Data sheets supplied with fibre optic cable should include the following installation information:

4.1.1 Identification of the fibre optic cable and the optical fibre used in its construction.

4.1.2 The length of cable on the spool.

4.1.3 Maximum tensile load during installation (N).

4.1.4 Maximum operational tensile load (N).

4.1.5 Minimum bend radius for installation and for operation at the specified operational tensile load (mm).

4.1.6 Storage temperature limits (C).

4.1.7 Installation temperature limits (C).

4.1.8 Operating temperature limits (C).

4.1.9 Cable OD (mm)

4.1.10 Cable weight per unit length (N/km).

4.1.11 Crush resistance, long term installed (N/cm).

4.1.12 Maximum vertical rise (m).

4.1.13 Optical attenuation per unit length (dB/km).

4.1.14 The length of cable on the spool.

4.1.15 The recommended method for cable support for vertical and horizontal installation, including the maximum distance between support points and minimum contact area with support mechanism, as applicable.

4.2 The above information should be supplied in accordance with EIA test procedures:

EIA-455-13 Visual and Mechanical Inspection of Fibres, Cables, Connectors, and/or other Fibre Optic Devices.

EIA-455-33 Fibre Optic Cable Tensile Loading and Bending Test.

EIA-455-37 Fibre Optic Cable Bend Test Low and High Temperature.

EIA-455-89 Fibre Optic Cable Jacket Elongation and Tensile Strength.

EIA-455-96 Fibre Optic Cable Storage Temperature Test*

* As of February. 1987, FOTP-96 is still in the preparation stage.

4.3 Optical cable should be compatible with the attachment mechanisms that are intended for structural penetration, strain relief and termination. Likewise, the optical fibre with any associated loose tubes, sub cable assemblies and strength members, should be compatible with the intended termination and splicing techniques.

5.0 Installation Requirements

5.1 Cable Locations

Cables of any description should be located with a view to avoiding spaces where excessive heat and gases may be encountered such as galleys, firerooms, and pumprooms, and spaces where there is a risk of damage such as cargo spaces and exposed sides of deck houses. Cables should not be located in cargo tanks, ballast tanks, fuel tanks, or water tanks except to supply equipment and instrumentation specifically designed for such locations and whose functions required it to be installed in the tank. Such equipment includes cargo monitoring instrumentation and underwater navigation systems.

Unless unavoidable, cables should not be located behind or embedded in structural heat insulation and where they pass through such insulation each cable should be protected by a continuous pipe, preferably fitted with a watertight stuffing tube at each end. For cables entering refrigerated compartments the pipe should be of heat-insulating material (fiber or phenolic tubing) joined to the bulkhead stuffing tube; alternatively a section of such material should be inserted between the bulkhead stuffing tube and the metallic pipe. Where cables are installed behind paneling, all connections should be readily accessible, and the location of concealed connection boxes should be indicated.

Cables in resistor rooms or in spaces occupied by resistors should be so arranged that their location directly over resistors is held to a minimum.

5.2 Cable Protection

All cables in bunkers and where particularly liable to damage such as locations in way of cargo ports, hatches, tank tops and where passing through decks should be specifically protected by removable metal coverings, angle irons, or other equivalent means. Horizontal pipes or equivalent used for cable protection should have 0.6 cm diameter holes for drainage every 1.5 m.

5.3 Cable Support and Retention

Cables, where installed in groups, should be supported, preferably in metal hangers, arranged as far as is practicable to permit painting surrounding structure without undue disturbance of the installation.

Clips or straps used for cable support should each be secured by two screws except that clips for supporting small diameter cable (1 cm) may be of the one-screw type provided that positive cable retention is provided.

Cable supports should be spaced in accordance with the manufacturers recommendations; in no case should they be more than 0.5 m apart.

Metal supports should be designed to secure cables without damage to armour or insulation and should be so arranged that the cable will bear for a length of at least 1.25 cm or in accordance with the manufacturer's instructions, whichever is greater.

Cable retention devices should be installed at every hanger on vertical runs, and not less than every fourth hanger on horizontal runs. Unless specified otherwise by the manufacturer, cable retention devices should be installed every 0.5 m on vertical tray installations and not less than every 2.5 m on horizontal tray installations. At turns of horizontal runs, cable retention devices should be spaced not more than 0.5 m apart. Metal cable retention devices are the preferred method for securing cables along horizontal and vertical cable runs.

Vertical Runs

The maximum vertical run for a cable shall not exceed the maximum distance as specified by the cable manufacturer. Where vertical cables runs of longer than the maximum specified are required, the cable should be run in intermediate, horizontal runs as required so that the maximum distance between horizontal sections does not exceed the maximum vertical run as specified by the manufacturer. The length of the horizontal portion of the cable run should not be less than 5% of the preceding vertical run.

5.4 Radius of Bends

The radius of bends should be as specified by the manufacturer but should not be less than 10 times the outer diameter (OD) of unarmored cables and 15 times the OD of armoured cables.

5.5 Cables Through Bulkheads, Decks, Beams, Etc.

Where cables pass through watertight bulkheads, a watertight transit or watertight stuffing tube, with suitable packing, should be employed. Cable transits should be used for multicable penetrations and stuffing tubes may be used for single and small diameter cables.

Where cables penetrate watertight decks, a kickpipe at least 30 cm high and a suitable stuffing tube should be used. For other than watertight decks, a kickpipe of at least 15 cm high should be used.

Where cables pass through nonwatertight bulkheads, beams, etc, a suitable bushing should be used of such a type as will permit pulling of the cable without damage. When the thickness of the bulkhead or web is 0.6 cm or more the bushing may be omitted but the edges of the holes should be rounded.

Where cables pass through fire boundaries, arrangements should be made to ensure that the integrity of the bulkhead is not impaired. Nonmetallic stuffing tubes should not be used in such penetrations. Cable transits and cable stuffing tubes should be fitted with a suitable fire blocking material.

5.6 Cable-Pulling-in Force

Cables should not be drawn into wireways where the required pull exceeds twenty times the weight of the cable within the wireway, and appliances should not be used which will damage the braid of armor. Cables should be pulled with bare hands and without the use of force multiplying devices.

5.7 Cable Pulling

For vertical applications, cable should be installed working from the top downward. When the use of pull ropes is required, a suitable pulling grip should be used. This grip should be:

- of the proper size for the cable
- able to provide an adequate means of transferring the pulling strain to the cable
- fitted with a swivel joint to prevent cable twist
- able to provide adequate protection to cable terminations when they are fitted prior to installation and to the cable end when there are no connectors fitted.

5.8 Cable Slack

Excess slack should not be left along the cable run. If there is a perceived requirement for additional cable a service loop may be installed. All of the normal cable requirements with regard to cable securement and bend radius apply to service loops. A sufficient length of cable should be provided at each end to allow for the cable to be terminated at least four times as well as to allow the associated equipment to be moved in and out of place or serviced as required. In lieu of this extra cable at the end of the run, extra cable may be stored in a service loop provided that the extra cable can readily be worked to the end where it may be required.

Cables and cable harnesses terminating at equipment mounted in racks, frames and consoles should be:

- of sufficient length and freedom to allow complete withdrawal of the equipment without the need to extend or close any other equipment slides;
- neatly run and secured to the frame so as not to impede the withdrawal of any equipment slide;
- secured to the mounted equipment in such a way that the securing point assumes any strain that might otherwise have been experienced by the connector, during equipment withdrawal.

5.9 Holes for Cables

The size of holes required for the installation of the cables for various systems should be such that they will not affect the structural strength of the various members through which they pass. However, if the size or position of the hole is such that the strength of the structural member is affected, suitable reinforcing of the structural member should be provided.

5.10 Cable Splicing

A cable may be spliced under the following conditions:

5.10.1 A cable installed in a structural subassembly may be spliced to a cable installed in another structural subassembly.

5.10.2 For a vessel receiving alterations, a cable may be spliced to extend a circuit.

5.10.3 A cable of exceptional length may be spliced to facilitate its installation.

5.10.4 A cable may be spliced to replace a damaged section of the cable, if before replacing the damaged section, the remainder of the cable is determined to be in good mechanical and optical condition.

Splices should be accessible. Cables for repeated flexing service should not be spliced.

Cable splicing should be in accordance with the Proposed Standard on mechanical and fusion splices for use with fibre optic cables.

Replacement cable jacket should be centered over the splice and overlap the existing cable jacket by at least 5 cm. The replacement cable jacket should be of such a diameter and be installed in such a way as to make a watertight seal with the existing cable jacket and should have physical properties that are the same as, equivalent to, or exceeding those of the original cable jacket.

Electrical continuity of metalic strength members and of the armour of armoured cable should be reestablished by a jumper of wire or braid or by replacement armour of the same material as the cable armour. The method of securing the replacement armour or jumper should not exert more pressure than is necessary to establish adequate electrical contact.

5.11 Cable Termination

A cable can be terminated in one of two ways: by splicing to another cable or pigtail or by connectoring. When terminated with a splice, the termination should be in compliance with the terms of the Proposed Standard for the shipboard use of fibre optic splices in addition to the terms of section 5.10 herein. When terminated with a connector, the termination should be in compliance with the terms of the Proposed Generic Specification of fiber optic connectors for shipboard applications in addition to the terms of section 5.8 herein.

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PROPOSED STANDARD FOR SHIPBOARD USE OF FIBRE OPTIC SOURCES, TRANSMITTERS, DETECTORS AND RECEIVERS

NOTICE

This proposed standard is designed to help eliminate misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. However the existence of this standard for shipboard use of fibre optic sources, transmitters, detectors and receivers does not preclude the use of products not conforming to the standard.

The standard is recommended without regard to patents or other proprietary rights. No liability is assumed in regard to such rights, nor is there any obligation to parties adopting the standard.

Reference Documents

TP 127E	Ship Safety Electrical Standards	
MIL-M-38510E(1)	Supp. 1B Microcircuits, General Specifications For	
EIA-509	Generic Specification for Fibre Optic Terminal Devices	
EIA-455-112	Power Supply Current	In Preparation (IP)
EIA-455-113	Digital Fibre Optic Terminal Devices General Measurement Requirements	IP
EIA-455-117	Optical Output Power	IP
EIA-455-119	Optical Sensitivity and Dynamic Range	IP

1.0 Definitions

1.1 Distinction Between An Optical Source and an Optical Transmitter

1.1.1 An optical source is a transducer which will convert an electrical signal to an optical signal in such a manner as to permit it to be coupled to an optical fibre without undue degradation of the data content.

1.1.2 An optical transmitter is a unit which will accept a specified electrical intput signal and provide an equivalent optical signal output suitable for coupling to an optical fibre. A transmitter must contain an optical source but, in addition, it also contains the necessary circuitry to precondition the electrical input signal as required so that it can modulate the optical source. Also, it must provide the necessary biasing and drive power for the optical source.

1.2 Distinction Between an Optical Detector and an Optical Receiver

1.2.1 An optical detector is a transducer which will convert an optical signal, as delivered by an optical fibre, to an electrical signal, in such a manner as to maintain the integrity of the signal, without undue degradation of the data content.

1.2.2 An optical receiver is a unit which will accept an optical input as delivered via an optical fibre and produce an equivalent electrical output which conforms to a specified electrical format. This electrical signal is compatible with the electrical circuit in which the receiver is used. An optical receiver contains and optical detector as well as the associated biasing circuits and the necessary amplification and conditioning circuits to produce the specified output.

1.3 Distinction between Long and Short Wavelengths

Wavelengths of interest in fibre optics range from 600 nm to 1600 nm. The low end of this range, from 600 to 1000 nm, is referred to as short wavelengths. Wavelengths from 1000 nm to 1600 nm are referred to as long wavelengths.

1.4 Pigtails

A pigtail is a length of fibre, usually cabled, permanently connected to a fibre optic device. For use with sources, transmitters, detectors and receivers, the intent is to improve coupling between these devices and the fibre core relative to coupling achieved with connector.

2.0 Applicable Documents

This Standard will be reviewed when EIA draft standards on sources, detectors, transducers and power supplies are available.

As fibre optic systems will be classified mostly under the application Controls and Instrumentation, the Transport Canada publication TP 127E section 22 may adequately address (with modification) the shipboard application of these devices. A copy as modified for shipboard usage is attached (Appendix A).

MIL-M-38510E(1) Supp. 1B Microcircuits, General Specifications for.

EIA-455-112 to EIA-455-119

3.0 Shipboard Requirements

For shipboard applications, the minimum requirements for sources, transmitters, detectors and receivers should not vary from those for land based systems. There are, however, some aspects which may require some additional considerations.

3.1 Reliability

TP127E-22 addresses reliability in a very broad manner. If a more detailed description of the reliability aspects of the components is required, it may be provided by the EIA standards when they are released or it can be taken from MIL-M-38510E(1) Supp. 1B, General Specifications for Microcircuits.

3.2 Power Supply

Fibre optic systems should be designed to operate within the guidelines set out in TP127E-22(10). This subject will also be reviewed when EIA standards on power supplies become available.

4.0 General Requirements for Sources, Transmitters, Detectors and Receivers.

4.1 The use of pigtails in transmitters and receivers is not recommended due to the potential for mechanical damage and the difficulties involved in maintenance, repair and testing.

4.2 The use of sockets for circuit board mounting is the preferred method to avoid unnecessary heating of transmitters and receivers during soldering. Manufacturers' recommendations may require some transmitters and receivers to be soldered directly to circuit boards.

4.3 Transmitters and receivers must be soldered or otherwise secured to printed circuit boards. If sockets are used, some form of positive mechanical retention must be provided. This means retention must be such that the device remains securely in place under all working environment conditions as well as protecting the device from damage or displacement when optical connectors are attached and disconnected.

4.4 The use of short wavelength sources is recommended. Long wavelength sources are both expensive and offer a lower flux budget than short wavelength sources.

4.5 Transmitters and receivers should be specified for use between the temperature extremes to which they will be exposed.

4.6 Transmitters and receivers should be kept as near to room temperature as possible. Ambient temperature variations should be kept to a minimum.

4.7 For purposes of system testing, printed circuit boards should have test points that are easily accessed. As a minimum, the following test points are required:

i. Transmitter power supply
ii. Transmitter input
iii. Receiver power supply
iv. Receiver digital output (for digital receivers)
v. Receiver analog output

4.8 Power supplies should be stable with a passive filter network as recommended by the manufacturer. The use of separate voltage regulators for each device is recommended.

4.9 Cables connected to the transmitters and receivers should be secured to the circuit board to avoid stress on the connectors or the transmitters and receivers.

5.0 Requirements for Sources and Transmitters

5.1 The optical output decreases with increasing temperature. Transmitters should be temperature cycled over the operating temperature range to determine the influence of this effect on system performance.

5.2 Output power must be measured for each transmitter before installation in a system. This is required for system design information and to determine the rate of source aging during system maintenance. The power should be measured in accordance with EIA-455-117.

6.0 Requirements for Dectectors and Receivers

6.1 When using very sensitive receivers, the possibility of spurious output from the receivers is possible. In some cases, the devices may oscillate at some fixed frequency. This effect depends on temperature, printed circuit board layout, power supply filtering, electromagnetic interference (EMI) and electromagnetic radiation (EMR). Special care must be taken with these parameters when designing printed circuit boards.

6.2 Avalanche photodiodes (APDs) require temperature compensation when operating at short wavelengths. The receiver should be cycled over the operating temperature range to ensure proper performance.

6.3 Sensitivity must be measured for each receiver before installation in a system. This is required for system design information and to determine the flux budget of an installed system. Sensitivity should be measured in accordance with EIA-455-119.

22. Control and Instrumentation

(1) Each apparatus shall possess a degree of reliability in accordance with the importance of the control system of which it forms a part.

(2) The design of the control equipment shall be such that a failure in the control equipment will cause the least dangerous condition of the controlled process and such failure shall not render any reserve automatic or manual control or both inoperative.

(3) Control and instrumentation circuits and this supply arrangments shall be so designed that failure of the power supply does not damage the installation nor endanger the ship.

(4) The repeatability and accuracy of instruments and control equipment shall be adequate for their proposed use and shall be maintained at their specified value during their expected lifetime and normal operative use.

(5) Electrical and electronic control equipment shall be suitable for the normal conditions encountered on shipboard.

(6)

(a) Control equipment shall operate satisfactorily in an air temperature range of 0 to 55 C and shall operate without deterioration in air temperature peaks of up to 70 C;

(b) Special consideration shall be given to equipment intended to be located in positions where extreme ambient temperatures are expected to exists; and

(c) The temperature rise inside equipment enclosures due to component heat dissipation shall be considered as well as the possible temperature increase due to radiation from hot machinery surfaces or from the sun.

(7) All control equipment shall operate satisfactorily under the following conditions of relative humidity:

- 100% r.h. at temperatures up to 40C; and
- 70% r.h. at all other relevant temperatures.

(8)

(a) Control equipment shall operate satisfactorily under the following vibration conditions:

- 2.0 - 13.2 Hz, displacement amplitude +/- 1.0mm
- 13.2 - 80.0 Hz, acceleration amplitude +/- .7g, maximum acceleration 0.7 g.

(b) Natural frequencies at supports for equipment and parts of equipment shall not lie within the 0-80Hz range, except that where they can not be kept outside this range by constructural design methods, the vibration shall be damped so that undue amplification is avoided.

(9) Control equipment shall remain fully operational under each of the following inclinations and movements of the ship:

- inclination in all directions from the mounting position 22.5 deg

- rolling 22.5 deg 10 seconds full period; and linear vertical acceleration of +/-1.0 g.

(10)

(a) Control equipment shall operate satisfactorily with the following variation from normal of the voltage and frequency of the a.c. power supplies to the equipment.

a.c.	Permanent Variation	Transient Variation	Recovery Time Seconds
Voltage	+/-10%	+/-20%	3
Frequency	+/-5%	+/-20%	3

(b) a.c. supplied equipment shall be capable of maintaining functional stability and accuracy with input supplies having a possible harmonic content up to 5%,

(c) for battery-supplied equipment voltage variations of +30% and-25% as determined by the charging/discharging characteristics, shall be taken into account, including ripple voltage from the charging device and

(d) when the equipment is not connected to the battery during charging or when voltage stabilizing equipment is used, these valus may be reduced to +/-20%

(e) when the equipment is vital to the safe operation of the vessel means shall be provided for a floating power supply, the operation of which is such that there is no interruption in the supply to the equipment when the vessel's main and emergency generating units fail.

(11) Circuits shall be designed for easy test, calibration, maintenance and repair; repair shall preferably be effected by unit or card replacement.

(12) The design of any circuit shall allow for variation in component data or drift within tolerances specified for the components.

(13) The system design shall be such that there will no undesirabl mutual effect between the different circuits; a failure of one component in a circuit shall, as far as practicable, not cause failure of components in other circuits.

(14) Design of circuits shall be such that there is no direct connection to any point of the ship's main power supply system, e.g. isolating transformers shall be used for power supplies; the chassis shall not form part of any circuit; extensive systems shall be sub-divided and the supplies individually protected; control circuits shall be separated from signalling and indicating circuits; faults in an indicating lamp circuit shall not impair the operation of the equipment or apparatus.

(15) Circuits which depend on the maintenance of high insulation resistance for their accurate functioning shall not be used unless special precautions are taken to maintain the high insulation resistance; such circuits shall be provided with means to check the insulation resistance.

(16) Signal levels of ship electrical cables shall be kept high enough to overcome the effects of contact corrosion, hum and noise pick-up.

(17) Signal levels of ship fibre optic cables shall be such that they meet the minimum flex budget requirements of the system when it is commissioned and also when component and system aging are considered over the expected life of the system and its components.

(18) Transducers and amplifiers shall be situated as close to each other as is practicable; to avoid possible interference on control and instrumentation cables, signal cables shall be either screened or twisted pairs and there shall be sufficient separation between signal and other cables.

(19) Section 22(18) shall not apply when fibre optic cable is used for signal cables between transducers and signal processing equipment.

PROPOSED STANDARD FOR THE SHIPBOARD USE OF FIBRE OPTIC COUPLERS

NOTICE

This proposed standard is designed to help eliminate misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. However the existence of this standard for shipboard use of fibre optic couplers does not preclude the use of products not conforming to the standard.

The standard is recommended without regard to patents or other proprietary rights. No liability is assumed in regard to such rights, nor is there any obligation to parties adopting the standard.

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Bedford, Nova Scotia

April, 1985.
Updated March, 1987.

Reference Documents

EIA-455-3	Temperature Cycling (Thermal Shock)
EIA-455-13	Visual and Mechanical Inspection of Fibres, Cables, Connectors and/or other Fibre Optic Devices
EIA-455-42	Optical Crosstalk in Fibre Optic Components
EIA-455-72	Procedure to Measure Temperature Cycling Effects in Fibre Optic Components
Note:	EIA-455-72 is in preparation by EIA.

SCOPE

The purpose of this standard is to recommend guidelines for the selection and use of optical components in shipboard applications. This standard can be applied to, but is not limited to, the selection of such components as:

optical couplers
optical splitters
optical attenuators
optical switches
optical multiplexers/demultiplexers

1.0 DEFINITIONS

1.1 Optical Devices

1.1.1 Coupler/monitor. Bidirectional Coupler - This device is designed for insertion into fibre cable, permitting low loss and mode independent monitoring of optical signal propagation in either direction.

1.1.2 Fibre Optic Splitter/Directional Coupler- A fibre optic splitter divides the input signal from one waveguide to output signals on two or more waveguides in a predetermined ratio. A signal fed into one of the output ports will appear at the input port only.

1.1.3 Optical Attenuator - An optical attenuator is a device used to introduce attenuation to an optical system in a controlled manner. Attenuators can be of the fixed or the variable type. Variable attenuators can be of the step variable or continuous variable type.

1.1.4 Optical Switch

1. An optical switch is a device which controls the direction of an optical signal from a selected input to a selected output under mechanical, electrical or magnetic control.
2. An optical switch is a device used to interrupt an optical signal in a controller manner under mechanical, electrical or magnetic control.

1.1.5 Star Coupler, Reflective (RSC) - A reflective star coupler is a device which accepts an optical input signal at any of the input/output ports and reflects that same signal out to each of the input/output ports including the original input port. It is bidirectional; each port can serve as both an input and an output port (see Figure 1).

1.1.6 Star Coupler, Transmissive (TSC) - A transmissive star coupler is a device which allows optical signals to be input via a number of input ports and be divided evenly among the output ports. It is unidirectional; input ports cannot be used as output ports or vice-versa (see Figure 2).

A transmissive star coupler differs from an optical splitter in that it has more than one input and the coupling ratio is the same for all of the output ports.

1.1.7 Wavelength Division Demultiplexer (WDD)- A wavelength division demultiplexer is a device which receives optical signals at two or more wavelengths from a single fibre, separates them and delivers components at each wavelength to a designated output fibre (Figure 3).

1.1.8 Wavelength Division Multiplexer (WDM)- A wavelength division multiplexer is a device which receives optical signals from two or more wavelength sources, each via its own input fibre, and delivers a composite output signal. made up of the sum of the input signals, to a single output (Figure 4).

1.2 Device Characteristics

1.2.1 Crosstalk

1. Crosstalk is the amount of optical energy at one wavelength reaching the output of a different wavelength in a WDD (Figure 5).

2. Crosstalk is the amount of light coupled into one waveguide from another waveguide.

Crosstalk is measured using the procedure given in EIA-455-42, Optical Crosstalk in Fibre Optic Components.

1.2.2 Insertion loss - Insertion loss is the power lost within an optical device including power lost to radiation, scattering, absorption, and coupling to isolated ports (See Figure 6).

1.2.3 Isolation - Isolation is the amount of light at one wavelength which appears at the input of a different wavelength in a WDM (Figure 7).

1.2.4 Switching Time - Switching time is the time required for an optical device such as an optical switch to change from one stable state to another.

2.0 ELECTRICAL REQUIREMENTS

Some optical devices require an electrical supply for control or switching functions. In some cases these devices will, in addition to the requirements of optical devices as indicated by this Standard, conform to requirements imposed upon them by the electrical standards governing the use of electrical devices according to the electrical classification into which they fall.

3.0 PERFORMANCE REQUIREMENTS

3.1 Insertion Loss

Acceptable levels of insertion loss vary according to the device being considered. In general, insertion loss levels must be such that, when combined with other system losses, an acceptable level of flux margin remains. For first order calculation of flux budget, insertion loss can be taken from device data sheets. For second order calculations, measured values should be used.

3.2 Aging

Changes in insertion losses due to component aging should be built into the system flux budget based on the life expectancy of the system, the projected loss increases due to component aging and the effect of aging acceleration due to the shipboard environment.

4.0 MECHANICAL REQUIREMENTS

4.1 Waveguide Connection

Waveguide connection to fibre optic devices can be by way of pigtails permanently fixed to the device and connected to other parts of the system with mechanical connectors or mechanical or fusion type splices, or by way of connectors fitted directly to the devices.

4.2 Packaging

The preferred method for packaging fibre optic devices is to encapsulate the device in a shock resistant package with an impact resistant outer cover. Means should be provided for securing the device so that when installed the device cannot move about independent of the structure to which it is mounted. Device packages should be no larger than is necessary to ensure their proper operation and to provide the required mechanical and environmental protection. Pigtails entering and exiting device packages should be provided with a means of protecting the fibre from being bent at a radius less than the minimum specified bend radius.

4.3 Mechanical Operation

Optical devices, such as optical switches, which have moving parts, should be so constructed and configured that the mechanical operation of these devices is not adversely affected by the normal vibrations and shock impulses in shipboard applications.

4.4 Inspection

Optical devices should be inspected using EIA-455-13, Visual and Mechanical Inspection of Fibres, Cables, Connectors and/or other Fibre Optic Devices.

5.0 ENVIRONMENTAL REQUIREMENTS

5.1 Packaging

To the extent possible with each device, the packaging of the device will be such that the optical components are isolated from the environment in which the device resides.

5.2 Temperature Cycling

When temperature cycled in accordance with EIA-455-72 the insertion loss and response time of the device should not vary such that the overall system performance is degraded beyond the limits of the flux margin, after the allowable flux loss for system aging has been taken into account.

5.3 Thermal Shock

When subject to thermal shock in accordance with the procedure given in EIA-455-3 the insertion loss and response time should not vary such that the overall system performance is degraded beyond the limits of the flux margin, after the allowable flux loss for system again has been taken into account.

5.4 Pigtails

Pigtails are the optical fibres extending from a device or component, which typically are spliced to other pigails or fibre in the process of system assembly. This contrasts to the use of connectors, which are used in locations where disassembly may be required and where the associated optical loss can be tolerated.

Pigtails should be sufficiently long to allow for a minimum of three reterminations, with sufficient length remaining for proper working of the pigtail and for proper storage.

5.4.1 Storage/Packaging

There should be a sufficient length of pigtail so that at no point is the fibre unduly stressed or bent at a radius smaller than the minimum as prescribed by the manufacturer. While in the storage position, the pigtail should be adequately supported so that it does not move about freely. If it is not possible to fully restrain the pigtail, and there is a possibility that it might oscillate due to machinery vibration or the motion of the vessel, the bend radius should be increased so that during vibrations the minimum bend radius is not exceeded.

5.4.2 Working Length

Sufficient length is required to allow the pigtail to reach between the components that it is connecting while still maintaining the minimum bend radius. In addition to this requirement, the pigtail should be of sufficient length to allow the end requiring termination or splicing to adequately reach the terminating or splicing equipment while allowing sufficient slack for the termination or splice to be performed.

5.4.3 Attachment

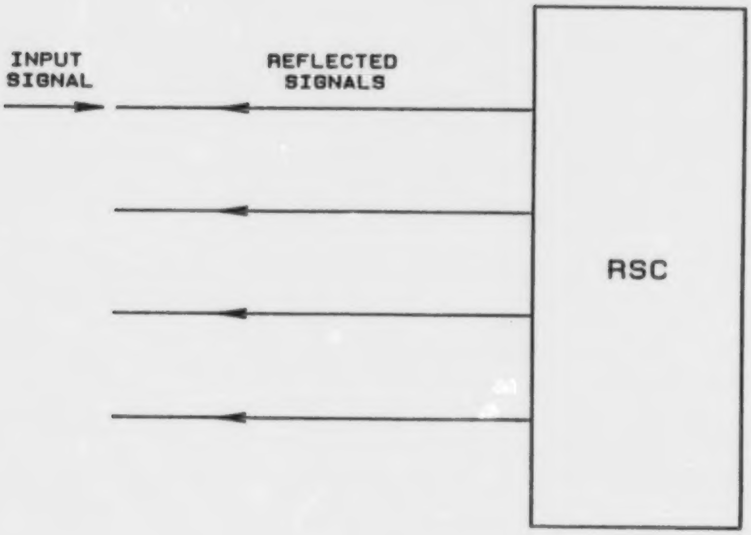
The manufacturer of the pigtailed devices for shipboard applications should provide adequate assurance that the pigtail is securely fastened to the device and will remain so under the combined effects of the operating environment.

5.4.4 Materials

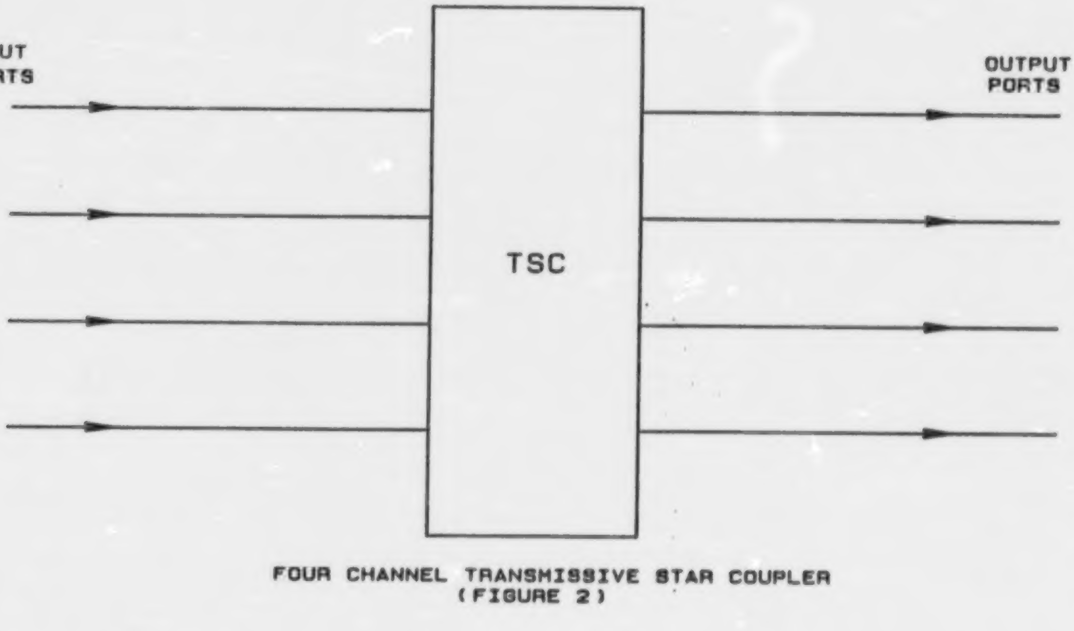
The materials used in and the methods used for the construction of pigtails should conform to the requirement for shipboard optical cable. The pigtail cabling or jacket should be compatible with the methods used to strain relieve the pigtail at the connector or splice.

5.4.5 Fibre Type

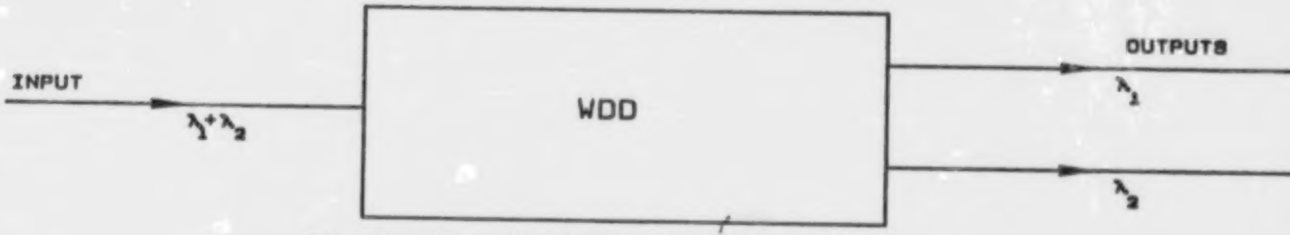
The optical fibre used in pigtails should be compatible with the fibre to which it is to be fusion spliced or should be compatible with the fibre and connectoring components to which it is to be connected or mechanically spliced.


INPUT
SIGNAL
REFLECTED
SIGNALS
RSC

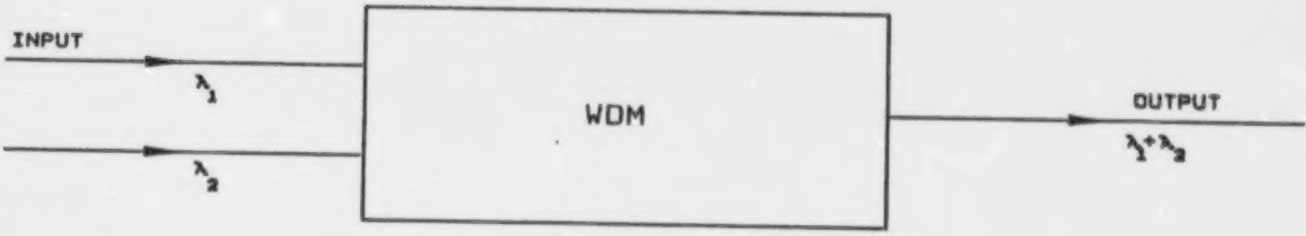
FOUR CHANNEL REFLECTIVE STAR COUPLER
(FIGURE 1)


INPUT
PORTS
TSC
OUTPUT
PORTS

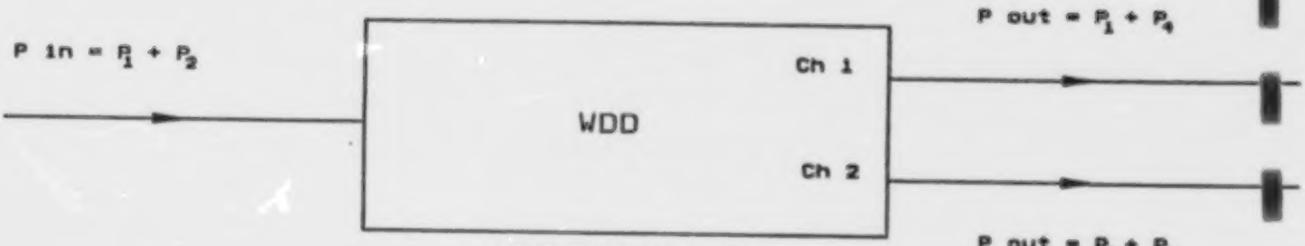
FOUR CHANNEL TRANSMISSIVE STAR COUPLER
(FIGURE 2)


INPUT
$\lambda_1+\lambda_2$
WDD
OUTPUTS
λ_1
λ_2

TWO CHANNEL WAVELENGTH DIVISION DEMULTIPLEXER
(FIGURE 3)


INPUT
λ_1
λ_2
WDM
OUTPUT
$\lambda_1+\lambda_2$

TWO CHANNEL WAVELENGTH DIVISION MULTIPLEXER
(FIGURE 4)


P in = $P_1 + P_2$
WDD
Ch 1
Ch 2
P out = $P_1 + P_4$
P out = $P_2 + P_3$

CROSSTALK IN A WDD
(FIGURE 5)

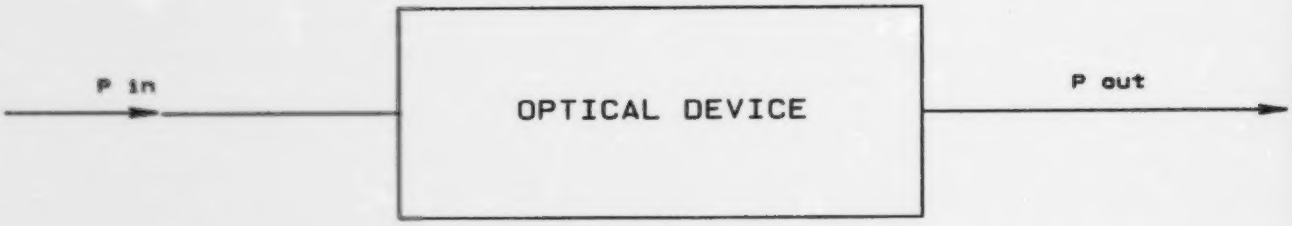
P_1 = INPUT POWER AT WAVELENGTH 1

P_2 = INPUT POWER AT WAVELENGTH 2

P_3 = POWER AT WAVELENGTH 1 WHICH APPEARS AT THE OUTPUT FOR WAVELENGTH 2

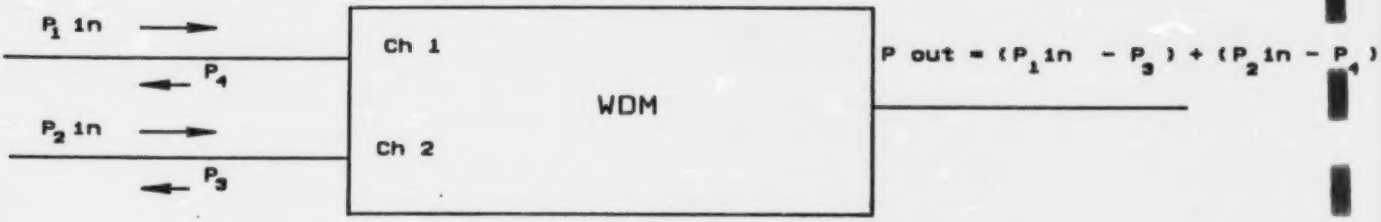
P_4 = POWER AT WAVELENGTH 2 WHICH APPEARS AT THE OUTPUT FOR WAVELENGTH 1

NOTE: THE OUTPUT POWERS ARE SHOWN AS A FIRST APPROXIMATION WITH NO CONSIDERATION GIVEN TO INSERTION LOSS.


P in
OPTICAL DEVICE
P out

INSERTION LOSS IN AN OPTICAL DEVICE
(FIGURE 6)

INSERTION LOSS (dB) = P in (dB) - P out (dB)


P_1 in
P_4
P_2 in
P_3
Ch 1
Ch 2
WDM
P out = (P_1 in - P_3) + (P_2 in - P_4)

ISOLATION IN A WDM
(FIGURE 7)

ISOLATION (Ch 1, dB) = P_1 in − P_3 (dB)

ISOLATION (Ch 2, dB) = P_2 in − P_4 (dB)

P_1 = INPUT POWER AT WAVELENGTH 1

P_2 = INPUT POWER AT WAVELENGTH 2

P_3 = POWER AT WAVELENGTH 1 PRESENT AT WAVELENGTH 2 INPUT

P_4 = POWER AT WAVELENGTH 2 PRESENT AT WAVELENGTH 1 INPUT

P out = WAVELENGTH 1 INPUT POWER LESS ISOLATION LOSS, P_3 , PLUS
WAVELENGTH 2 INPUT POWER LESS ISOLATION LOSS, P_4

DRAFT

PROPOSED GENERIC SPECIFICATION
FOR FIBRE OPTIC CONNECTORS
FOR SHIPBOARD APPLICATIONS

NOTICE

This Proposed Standard is designed to help eliminate misunderstandings between manufacturers and purchasers, facilitate interchangeability and improvement of products, and assist the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. However the existence of this standard for the generic specification of fibre optic connectors for shipboard applications does not preclude the use of other connectors not conforming to the standard.

This Standard is recommended without regard to patents or other proprietary rights. No liability is assumed in regard to such rights, nor is there any obligation to parties adopting the Standards.

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April, 1985.
Updated March, 1987.

Modification of Existing Documents

EIA-475 was prepared for the general use of fibre optic connectors but most of it applies to shipboard use. The exceptions are as follows:

Exception 1. Page 2. Add to the list of Applicable Documents as follows:

2.4 Military Standard (MIL-STD)

MIL-STD-1344 Test Methods for Electrical Connectors.

Exception 2. Page 8. Renumber paragraph 6.20 as 6.22 and add the following:

6.20 Flammability

When tested as specified in accordance with Method 1012 of MIL-STD-1344, materials used in the construction of the connector shall not support combustion for more than 3 seconds and optical integrity (less then 1 dB loss) shall be maintained for 30 seconds.

6.21 Icing

Connectors which are intended to be exposed to the weather shall not be damaged when tested with black ice producing a pressure of 0.2 kPa upon the side of the connector housing. Coupling devices shall not freeze in position.

Exception 3. Add to paragraph 7.7.17 a reference to the following fluids:

gasoline
diesel fuel
anti-icing fluid
mineral spirits

These fluids are to be added to EIA-455-12.

Exception 4. Page 16. Renumber paragraph 7.7.21 as 7.7.23 and add the following:

7.7.21 Flammability

Flammability testing shall be in accordance with Method 1012 of MIL-STD-1344.

7.7.22 Icing

Black ice producing a pressure of 0.2 kPa upon the side of the connector housing shall be used.

A version of EIA-475 modified to include the above changes has been attached for reference.

PROPOSED GENERIC SPECIFICATION FOR FIBRE OPTIC CONNECTORS FOR SHIPBOARD APPLICATIONS

(From EIA Standards Proposal No. 1402, formulated under the cognizance of EIA P-6.3 Working Group on Fibre Optic Interconnecting Devices and modified for shipboard applications).

INTRODUCTION

This standard was formulated for the purpose of:

(a) Promoting interchangeability of fibre optic interconnections

(b) Elimination of misunderstandings or confusion between manufacturers and buyers with respect to product performance requirements.

EIA-475 applies to fibre optic interconnecting devices intended for use in optical waveguide communications. This Generic Specification and accompanying Sectional and Detail Specifications follow the specification structure used in the IEC Quality Assessment System for Electronic Components (IECQ-System). A brief description of this specification system is found in Appendix B.

SIMILARITY WITH IEC RECOMMENDATIONS

This EIA Recommended Standard will be coordinated with the work of IEC Subcommittee SC46E.

1.0 Scope

This EIA Recommended Standard, which is a generic specification, relates to fibre optic interconnecting devices for use in optical waveguide communication. Interconnecting devices covered by this Standard include separable connectors used to terminate optical waveguides to optical waveguides and to discrete devices (see paragraph 9.0 herein).

Interconnecting device types may be for a single fibre or fibre bundle cables or both. The cables may contain termini for glass or plastic fibres or combinations of these. Other types of contacts such as electrical or fluid may also be included in the same device. The device may be for single or multiple channels.

Individual connector types shall be described in a sectional specification that will include a Blank Detail Specification along with instructions on how a onnector manufacturer may convert a Detail Specification through the addition of performance characteristics of his particular product, referencing those applicable requirements from Paragraph 6.0.

NOTE 1: Blank Detail Specification, from which a connector manufacturer may develop a Detail Specification by filling in performance data on his product, are under development to be included in a Sectional Specification.

Unless otherwise specified in the Detail Specification, all connectors shall meet the requirements of Table I, Group I, including Detail Specification criteria. Environmental connectors shall also meet the requirements of Groups 2 and 3. Where this specification conflicts with the Detail Specification, the Detail Specification shall take precedence (see paragraph 9.0 herein).

2.0 APPLICABLE DOCUMENTS

The following documents of the issue in effect form a part of the Standard to the extent specified herein.

2.1 Electronic Industries Association (EIA)

EIA-440	Fibre Optic Connector Terminology
EIA-455	Standard Test Procedures for Fibre Optic Fibres, Cables, Transducers, Connecting and Terminating Devices

2.2 American National Standards Institute (ANSI)

ANSI ZI.4	Quality Assurance
ANSI ZI.9	Quality Assurance
ANSI Z310.1	Recommended Practice for Determining, Resistance of Synthetic Polymeric Materials to Fungi (ASTM G21)
ANSI Z136.1	Safe Use of Lasers

2.3 Government Services Administration (GSA)

FED-STD-28	Screw Thread Standard for the Federal Government, Parts 1, 2 and 3.

2.4 Military Standard (MIL-STD)

MIL-STD-1344	Test Methods for Electrical Connectors

3.0 CLASSIFICATION

TYPE

Plugs -	Plugs are normally attached to the cable and incorporate the dynamic portion of the mechanical coupling mechanism.
Receptacles -	Receptacles may be rigidly mounted to a panel and/or attached to a cable and incorporate the static portion of the mechanical coupling mechanism.

CLASS

Class 1 - Capable of terminating one or more single optical fibres/cable

Class 2 - Capable of terminating one or more fibre bundle/cable

Class 3 - Hybrid Connector: in addition to terminating one or more optical fibres/cable types (single or bundle), it may be capable of terminating one or more electrical, fluid or other conductors.

4.0 DEFINITIONS

See EIA-440 "Fibre Optic Connector Terminology."

5.0 DESIGN REQUIREMENTS

5.1 Detail requirements shall be specified by the Detail Specification.

5.2 Materials

Materials shall be as specified herein. Materials which are not specified shall be of the lightest practical mass and suitable for the intended purpose.

5.3 Design and Construction

5.3.1 Fibre optic connectors shall be of the design, construction, and physical dimensions specified bythe Sectional and Detail Specification

5.3.2 If threads are used for removeable parts, they shall be metric in accordance with GSA FED-STD-28

5.3.3 Dissimilar Metals

Sissimilar metals employed in intimate contact with each other shall have suitable protection against electrolytic corrosion

5.3.4 Mounting means shall be as specified in the Detail Specification

5.3.5 Coupling Device

Unless otherwise specified, the connector shall be capable of being mated and unmated without the use of special tools, with exception of systems utilizing laser sources.

5.3.6 Polarization

Multichannel connectors must be keyed to prevent mating when corresponding termini/contacts are not aligned. Polarization of the counter part connectors shall take place before coupling devices are engaged

5.3.7 Component Hardware

The connector and its components shall be fabricated from materials normally resistant to corrosion or materials that can be finished to prevent corrosion, i.e., austenitic stainless steel

5.3.8 Finishes

Peeling or chipping of the allowable plating or finishes, galling of mating parts, nicks, burrs or other surface blemishes shall not be permitted

5.3.9 Adhesive and Sealing Compounds

When specified, the connector manufacturer shall specify necessary adhesives for terminating the optical fibre or for sealing the connector

5.3.10 Non-Toxic and Non-Hazardous

The connectors shall not release toxic or explosive fumes exceeding the limits specified when exposed to flame or chemical agents commonly used in the environment in which the connectors are intended for use

5.3.11 Fungus Resistance

When specified, the materials employed shall be resistant to fungus growth

5.3.12 Cleaning

The design of the connector shall permit cleaning of the optical face of the terminus without requiring disassembly of the connector or removal of the terminus from the connector. The connector shall not be softened, embrittled, etched, or otherwise affected by the optical cleaning agent

5.3.13 Scoop Proof

The connector design shall prevent damage to the optical interfaces or electrical contacts when encountering the interface ends of the connector during mating

5.3.14 Sealing

When specified, the connector design shall include environmental sealing capabilities at the interface and rear of the connector. The seals, dynamic, static or both, shall preclude the entrance of moisture, dust, sand and dirt that might degrade the performance required under specified environmental conditions

5.3.15 Cable Strength Member Terminations

The termination of the cable strength member shall be such that any specified force applied to the cable will not damage the optical fibres or degrade optical performance beyond specified limits

5.3.16 Cable Strain Relief

As specified, the cable strain relief shall grip the cable as it exists the connector to prevent degradation of optical performance by:

(1) Cable flexing or twisting at or near the termination

(2) Cable pull out by tensile forces

5.3.17 Terminus Retention

The optical terminus shall withstand an axial force as specified from the optical surface end of the connector.

5.3.18 Terminus Outlines

Termini shall be sufficiently specified on the Detail Specification sheets to ensure intermateability and interchangeability

5.3.19 Termination Process

The termination procedure, including the fibre/cable preparation, shall be supplied by the connector manufacturer when specified

5.3.20 Index Matching Fluids

When index matching fluids are required, they shall be as specified by the connector manufacturer on the Detail Specification

5.3.21 Safety

When specified, the connector shall meet the requirements of the referenced Safety Standards ANSI Z136.1

5.3.22 Size

The physical size and insert arrangement shall be as specified by the Detail Specification

5.4 Part Numbering and Marking

Each connector covered by this Standard as outlined in an EIA Sectional Detail Specification shall be assigned a discrete part number in accordance with Appendix A.

Other markings may be applied to the fibre optic connector provided they do not interfere with, obscure, or confuse the part number specified above. Where size, surface condition, or other design considerations will not allow full marking on the part, the markings shall be in the order of preference shown below. Any required marking which cannot be applied to the connector shall be applied to the unit package.

6.0 PERFORMANCE REQUIREMENTS

6.1 Insertion Loss

When tested in accordance with Paragraph 7.7.2, the connector insertion loss shall be as specified in the Detail Specification for the connector being tested.

6.2 Temperature Cycling

When tested in accordance with Paragraph 7.7.3, there shall be no damage detrimental to the operation of the connector. The connector insertion loss shall not exceed the limits as specified in the Detail Specification.

6.3 Durability

When tested as specified in Paragraph 7.7.4, the connector shall show no defects detrimental to the operation of the connector and shall have coupling forces and insertion losses within the requirements specified in the Detail Specification.

6.4 Coupling Forces

When tested as specified in Paragraph 7.7.5, the coupling forces and torques for mating and unmating of the counter part connectors shall meet the requirements as specified in the Detail Specification.

6.5 Twist Test

When tested as specified in Paragraph 7.7.19, the cable/connector interface shall have no damage detrimental to the operation of the cable or connector. The connector insertion loss shall not exceed the limits specified in the Detail Specification.

6.6 Flex Test

When tested as specified in Paragraph 7.7.6, the cable/connector interface shall have no damage detrimental to the operation of the cable or connector. The connector insertion loss shall not exceed the limits specified in the Detail Specification.

6.7 Cable Retention

When tested as specified in Paragraph 7.7.7, there shall be no evidence of damage detrimental to the operation of the cable/connector, and the connector insertion loss shall be within the limits specified in the Detail Specification.

6.8 Maintenance Aging (Multi-Terminus Connectors)

When tested as specified in Paragraph 7.7.8, the contact installing and removal forces shall not exceed the requirements in the Detail Specification. The connector insertion loss shall be within the limits specified in the Detail Specification.

6.9 Vibration

When tested as specified in Paragraph 7.7.9, there shall be no transient change in optical transmittance beyond specification limits and there shall be no disengagement of the mated connectors, backing off from the coupling mechanism, evidence of cracking, breaking, or loosening of parts. Insertion loss shall not exceed the requirements specified in the Detail Specification.

6.10 Shock

When tested as specified in Paragraph 7.7.10, there shall be no transient change in optical transmittance beyond specification limits and there shall be no disengagement of the mated connectors, evidence of cracking, breaking or loosening of parts. Insertion loss shall not exceed the requirements specified in the Detail Specification.

6.11 Impact Test

When tested as specified in Paragraph 7.7.11, connectors shall show no evidence of damage detrimental to their normal operation nor a degradation in insertion loss beyond the limits specified in the Detail Specification.

6.12 Acceleration

When tested as specified in Paragraph 7.7.12, there shall be no transient change in optical transmittance beyond specification limits and there shall be no disengagement of the mated connectors, evidence of cracking, breaking or loosening of parts. Insertion loss shall be as specified in the Detail Specification.

6.13 Humidity

When tested as specified in 7.7.13, assembled, mated connectors shall show no deterioration which will adversely affect performance of the connector. During the following the test, insertion loss shall be as specified in the Detail Specification.

6.14 Industrial Atmosphere

When tested as specified in 7.7.14 assembled, mated connectors shall show no deterioration which will adversely affect performance (insertion loss, etc) of the connectors beyond the limits as specified in the Detail Specification.

6.15 Salt Spray

When tested as specified in 7.7.15, unmated connectors shall now show exposure of base matel or corrosion products which will adversely affect performance. Following the test, insertion loss shall be as specified in the Detail Specification.

6.16 Altitude

When tested as specified in 7.7.16, assembled, mated connectors shall show no deterioration which will adversely affect performance of the connectors. Insertion loss shall be in accordance with the Detail Specification.

6.17 Fluid Immersion

When tested as specified in 7.7.17, connectors shall meet the requirements for coupling forces (see Paragraph 6.1 herein) and insertion loss (see Paragraph 6.1 herein) and insertion loss (see Paragraph 6.1 herein).

6.18 Temperature Life

When tested as specified in 7.7.18, connectors shall perform satisfactorily and meet the requirements for insertion loss (see paragraph 6.1, herein).

6.19 Sand and Dust

When tested as specified in 7.7.20, connector shall show no defects detrimental to the operation of the connector and shall have coupling forces and insertion losses within the requirements specified in the Detail Specification.

6.20 Flammability

When tested as specified in accordance with Method 1012 of MIL-STD-1344, materials used in the construction of the connector shall not support combustion for more than 3 seconds and optical integrity (less then 1 dB loss) shall be maintained for 30 seconds.

6.21 Icing

Connectors which are intended to be exposed to the weather shall not be damaged when tested with black ice producing a pressure of 0.2 kPa upon the side of the connector housing. Coupling devices shall not freeze in position.

6.22 Post-Test Examination of Product

When inspected as specified in Paragraph 7.7.21, the connectors shall have legible marking, there shall be no cracks in the materials used in the connectors and there shall be no corrosion products that affect fit or function.

7.0 QUALITY ASSURANCE

7.1 Qualification

Qualification shall be evidenced by data, certified by an officer of the manufacturing company or other appropriate source, attesting to compliance of the product with design and performance requirements of this Standard and applicable Detail Specification. Qualification tests outlined in Paragraph 7.5 shall be performed on fibre optic connectors described in Paragraph 7.2 produced, where possible, utilizing the same equipment and procedures normally used for manufacturing the product. Failure of any sample to comply with the specified requirements shall be cause for refusal to grant qualification approval. Each qualification test sample shall have passed the Quality Conformance Inspection. In addition to the qualification tests, the manufacturer shall provide a certification attesting to the compliance of the product(s) to the specified design requirements. Fibre Optic Test Procedures (FOTP's) called out in this Section are found in EIA Recommended Standard 455, and Addendums to that Standard, except as noted through appropriate footnotes.

7.2 Single Product Approval

When qualification is sought for only one particular product, described in one Detail Specification, three mated pairs of test samples per test group shall be subjected to the tests of Table I in the sequence shown. Qualification approval is restricted to that particular product. The product to be qualified does not necessarily have to be tested to all test groups of Table I in order to be qualified. The Detail Specification shall list the required tests.

7.3 Multiple Product Approval

When qualification approval is sought for a group of products covered by a single Detail Specification, the requirement of paragraph 7.1 shall be met on a selected connector pair. The qualification test on the addition connectors shall consist of the quality conformance inspection on each mated pair.

7.4 Test Conditions

Unless specified atmospheric conditions are specified in the individual test method, all measurements and tests are to be performed under the following standard laboratory conditions:

Temperature	15 degrees C to 35 degrees C
Relative Humidity	20 % to 80 %
Atmospheric Pressure	86 to 106 kPa

The fibre optic connector shall be allowed sufficient time to reach thermal stability before performing measurements under standard atmospheric conditions. All tests and measurements shall be performed on fibre optic connectors as received from the supplier without any cleaning or other preparation except as specified by the individual test method and/or by the user instructions. When the test requires, the fibre optic connector will be mounted directly on a metal plate by its normal mounting means. The plate shall be larger than the connector. Unless explicitly stated in the Detail Specification, the optical interface shall be cleaned prior to each test. Optical degradation after each test shall be specified in the Detail Specification. When a cable has to be assembled to the connector, assembly instructions shall be followed as supplied by the connector manufacturer. Connector pairs shall be completely coupled as specified by the manufacturers.

7.5 Qualification Test

Samples provided by paragraph 7.2 shall be tested to the test groups of Table I in the sequence listed below:

TABLE I

Group 1 (General)	Requirement Paragraph	Test Paragraph
Examination of Product (Pre Test)	5.0	7.7.1
Insertion Loss	6.1	7.7.2
Temperature Cycling	6.2	7.7.3
Durability	6.3	7.7.4
Coupling Forces	6.4	7.7.5
Flex Test	6.6	7.7.6
Twist Test	6.5	7.7.19
Cable Retention	6.7	7.7.7
Examination of Product (Post Test)	6.20	7.7.21

TABLE I (Continued)

Group 2 (Mechanical)	Requirement Paragraph	Test Paragraph
Examination of Product (Pre-Test)	5.0	7.7.1
Insertion Loss	6.1	7.7.2
Maintenance Aging	6.8	7.7.8
Temperature Cycling	6.2	7.7.3
Vibration	6.9	7.7.9
Shock	6.10	7.7.10
Impact Test	6.11	7.7.11
Acceleration	6.12	7.7.12
Sand and Dust	6.19	7.7.20
Examination of Product (Post Test)	6.20	7.7.21

Group 3 (Environmental)	Requirement Paragraph	Test Paragraph
Examination of Product (Pre-Test)	5.0	7.7.1
Insertion Loss	6.1	7.7.2
Temperature Cycling	6.2	7.7.3
Humidity	6.13	7.7.13
Industrial Atmosphere	6.14	7.7.14
Salt Spray	6.15	7.7.15
Altitude	6.16	7.7.16
Fluid Immersion	6.17	7.7.17
Maintenance Aging	6.8	7.7.8
Temperature Life	6.18	7.7.18
Examination of Product (Post Test)	6.20	7.7.21

7.6 Quality Conformance Inspection

The Quality Conformance Inspection shall consist of the tests specified in Table II and shall be performed on each production lot.

7.6.1 Inspection Lot

An inspection lot shall consist of all connectors covered by the same Detail Specification meeting the same design and performance requirements, produced under essentially the same conditions and offered for inspection at one time.

7.6.2 Rejected Lots

If an inspection lot is rejected, the supplier may either rework the lot to correct the cause of rejection or inspect each product for that parameter causing the rejection to screen out the defective units.

TABLE II

QUALITY CONFORMANCE INSPECTION

Test	Requirement Paragraph	AQL1/ Major	Minor
Visual Examination 2/	7.7.1	1.0	4.0
Insertion Loss 3/	7.7.2		

1/ The AQL (Acceptance Quality Level) percentage values listed in Table II should be considered the minimum quality level in range of AQL's that decrease numerically to zero to reflect higher quality levels. If the user of this Standard as a procurement specification desires a different AQL, the user should negotiate a specific AQL with the component producer. Absent this negotiation, it is assumed that the AQL's listed in Table II for the indicated test will be satisfactory to the user. AQL's shall be per ANSI Standard Z1.4 "Quality Assurance". ANSI Standard Z1.9 can also be used if so specified.

2/ The Detail Specification shall define the major and minor characteristics for visual inspection.

3/ This test can be considered to be destructive if the connector is to be shipped less cable. It shall be tested 100% on all terminated connectors and on one connector per lot for those not to be supplied with cable.

7.7 Method of Examination and Test

7.7.1 Visual and Mechanical Examination (Pre-Test)

The connectors, accessories, and piece parts shall be visually and mechanically examined to ensure conformance with this specification and the applicable design standard in accordance with EIA-455-13 "Visual Examination of Product."

7.7.2 Insertion Loss

See paragraph 6.1. Connectors will be tested in accordance with EIA-455-9 "Fibre Optic Test Procedure for Budnle Connector Insertion Loss" and EIA-455-34 "Insertion Loss for Single Fiber Connectors and Cable Assembly." The loss measured shall be measured at the optical wavelength as specified in the Detail Specification.

7.7.3 Temperature Cycling

See paragraph 6.2. Mated connectors shall be subjected to the temperature cycling of EIA-455-3 "Temperature Cycling of Fiber Optic Connectors (Thermal Shock)". Test condition shall be listed on the Detail Specification. The change in insertion loss during and after temperature cycling shall be measured.

7.7.4 Durability

See paragraph 6.3. The terminated, assembled plugs and receptacles shall be mated and unmated for 250 cycles as required by EIA-455-21 "Durability" at a maximum rate of 300 cycles per hour. The mating and unmating will be accomplished so that the plug and receptacle are completely separated during each cycle. The change in insertion loss and coupling forces after the durability test shall be measured. When called for as a normal part of the coupling procedure in the

Detail Specification, the connector shall be cleaned prior to insertion loss and/or coupling force measurements.

7.7.5 Coupling Forces

See paragraph 6.7. For qualification testing, mating halves shall be coupled and uncoupled; the forces or torques which must be applied to facilitate full coupling and uncoupling shall be measured and recorded.

7.7.6 Flex Test

See paragraph 6.6. The cable/connector junction shall be flexed for the number of cycles using the load specified in the Detail Specification according to EIA-455-1 "Cable Flexing for Fiber Optic Connectors". The change in insertion loss shall be measured during and after the flex test.

7.7.7 Cable Retention

See paragraph 6.7. The cable/connector junction shall have the test load applied according to EIA-455-6 "Cable Retention Test Procedure for Fibre Optic Cable Interconnecting Devices". The loads number of cycles shall be specified in the Detail Specification. The change in insertion loss shall be measuring during and after the retention load has been applied.

7.7.8 Maintenance Aging

See paragraph 6.8. Connectors shall be tested in accordance with EIA-455-3 "Maintenance Aging". The installing/removal tool shall be in accordance with that specified in the Detail Specification. The terminus installing/removal force and the change in insertion loss shall be measured after maintenance aging.

7.7.9 Vibration

See paragraph 6.9. Mated connectors shall be subjected to the test specified in Test Condition II, paragraph 7.1.4 of EIA-455-11 "Vibration Test Procedure for Fiber Optic Connecting Devices" at room temperature. The change in insertion loss shall be measured during and after the vibration test.

7.7.10 Shock

See paragraph 6.10. Mated connectors shall be subjected to the test specified in FOTP #14 "Shock EIA-455-14 (Specified Pulse)". The following details shall apply:

(a) The pulse shall be an approximate half sinewave of 300 G +/- 15% magnitude with a duration of 3 +/- 1 ms.

(b) The cable shall be clamped to the shock table approximately 200 mm (7.87 inches) from the rear of the connector.

(c) The change in insertion loss shall be measured after the shock test.

7.7.11 Impact Test

See paragraph 6.11. Each plug and receptacle of each connector to be qualified shall be subjected to the test according to EIA-455-2 "Impact Test Measurements". The change in insertion loss shall be measured after the impact test.

7.7.12 Accleration

See paragraph 6.12. Mated connectors shall be subjected to the acceleration forces of Test Condition A1, paragraph 4.2 of EIA-455-18 "Acceleration". The change in insertion loss shall be measured during and after the acceleration test.

7.7.13 Humidity

See paragraph 6.13. Mated connectors shall be subjected to the humidity test specified in FOTP #5 EIA-455-5 "Humidity Test Procedure for Fiber Optic Connecting Devices". The following details and exceptions shall apply:

(a) The mated connectors shall be mounted in a vertical position.

(b) Three hours minimum after completion of the last cycle and while the connectors are still subjected to high humidity, the insertion loss shall be measured when the temperature reaches 20 degrees C and condensation is observed on the connector.

(c) The change in insertion loss shall be measured at room ambience 3 house after the last cycle.

7.7.14 Industrial Atmosphere

See paragraph 6.14. The mated connectors shall be subjected to the conditions specified in EIA-455-19 "Flowing Gas Simulated Industry Atmosphere Test". The change in insertion loss shall be measured after the test.

7.7.15 Salt Spray

See paragraph 6.15. Connectors shall be tested in accordance with EIA-455-16 "Salt Spray (Corrosion)". The following details and exceptions shall apply:

(a) Test Condition Letter B.

(b) The samples shall not be mounted, but shall be suspended from the top of the chamber using waxed twine or string, glass rods or glass cord.

(c) Cable ends shall be protected to prevent salt migration.

(d) The change in insertion loss shall be measured after the post-cleaning.

7.7.16 Altitude

See paragraph 6.16. Mated connectors shall be tested in accordance with EIA-455-15 "Altitude Immersion" as specified in the Detail Specification. The change in insertion loss shall be measured after the test.

7.7.17 Fluid Immersion

See paragraph 6.17. Connectors shall be immersed in the fluids specified in the Detail Specification according to EIA-455-12 "Fluid Immersion Test Procedure for Fibre Optic Connecting Devices" as modified to include gasoline, diesel fuel, anti-icing fluid and mineral spirits. The fluid temperature, number of cycles, and whether mated or unmated shall be specified in the Detail Specification. After immersion and cleaning as required, coupling forces and the change in insertion loss shall be measured.

7.7.18 Temperature Life

See paragraph 6.18. Mated connectors shall be subjected to an ambient temperature test condition and test time condition of EIA-455-4 "Fibre Optic Connector Temperature Life", as specified in the Detail Specification. The change in insertion loss shall be measured during and after the test.

7.7.19 Twist Test

See paragraph 6.7. The cable/connector junction shall be twisted for the number of cycles specified in the Detail Specification according to EIA-455-36 "Twist Test for Fiber Optic Connectors." Insertion loss shall be monitored during and after the test.

7.7.20 Sand and Dust

See paragraph 6.19. Mated connectors shall be tested in accordance with EIA-455-35 "Fibre Optic Connector Sand and Dust Test" at room temperature. The change in insertion loss and coupling forces shall be measured after the exposure.

7.7.21 Flammability

Flammability testing shall be in accordance with Method 1012 of MIL-STD-1344.

7.7.22 Icing

Black ice producing a pressure of 0.2 kPa upon the side of the connector housing shall be used.

7.7.23 Examination of Product - Post-Test

See paragraph 6.20. Connectors shall be inspected for conditions including, but not necessarily limited to, the following:

(a) Dimensional changes in excess of specified limits.

(b) Hardening or softening of dielectric materials in excess of specified limits.

(c) Opening of seals.

(d) Cracking or crazing or delamination of components or finishes.

(e) Fusing or seizure of mating connectors or components.

(f) Leakage of potting materials.

The above conditions shall be judged on their effect on the continued successful operation of the connector and the ability of the connector to meet the test requirements of the individual applicable specifications.

8.0 PACKAGING REQUIREMENTS

The requirements for packaging shall be in accordance with the Detail Specification.

9.0 APPLICATION NOTES

This generic specification must be used in conjunction with a Sectional and corresponding Detail Specification which defines specific values for the performance requirements. The Detail Specification takes precedence over the requirements of the generic and Sectional Specification and may add, delete, or modify the requirements of these higher tier documents. The buyer may utilize a Detail Specification issued by EIA or, if necessary, he or the connector manufacturer may prepare his own Detail Specification from the Blank Detail Specification. The EIA Detail Specifications assign a unique part number to each particular fibre optic connector configuration covered by the Design Specification. This part number is adequate to use for procurement of a standard fiber optic connector. A standard fibre optic connector is considered to be a fibre optic connector which is described in an EIA Detail Specification. A special fibre optic connector is considered to be a fibre optic connector which is not described by an EIA Detail Specification. An EIA part number may be assigned only to standard fibre optic connectors.

When a special fibre optic connector is required, the buyer may prepare a Detail Specification which fully describes the special fibre optic connector. If the required special fibre optic connector is different than the types described by the EIA Detail Specification, a complete new Detail Specification must be prepared. If the required special fibre optic connector is similar to the fibre optic connector types described by an EIA Detail Specification, the buyer may prepare a Detail Specification by referencing the part number of the standard fibre optic connector and specifying the differences required between the special connector and the standard fibre optic connector.

APPENDIX A

EIA PART NUMBERING AND CODING SYSTEM

1. Part Numbering

The EIA part number is formed by selecting a variable, if applicable, from the coding system shown below:

EIA475-X-

U.S.A. National Standards Organization

This (Generic) Standard Number

Detail Specification Number

Discrete Connector Identification
from the EIA Detail Specification

2. Coding System

A discrete connector identification and coding system to complete the EIA standard connector part number is found in the EIA Detail Specification along with other marking requirements.

APPENDIX B

INTRODUCTION TO THE IEC QUALITY ASSESSMENT SYSTEM FOR ELECTRONIC COMPONENTS (IECQ-SYSTEM) SPECIFICATION STRUCTURE

Four levels of specifications are provided for use in the IECQ-System. These are Basic, Generic, Sectional, and Detail Specifications. The following is a summary description of each of these specification levels:

(a) Basic Specifications. Basic Specifications are those which contain information common to electronic components or to a number of component families such as specifications and standards dealing with marking codes, preferred number series, basic environmental testing procedures, and sampling plans and procedures for inspection by attributes. Basic Specifications are referenced in Generic or Sectional Specifications.

(b) General Specifications. Generic Specifications are those which contain terms and definitions, and methods of measurement and tests that are mainly common to a family of components. Generic specifications also including marking of components and packages, along with quality assessment procedures, and qualification approval and quality conformance inspection procedures.

(c) Sectional Specifications. Sectional Specifications are prepared in accordance with the requirements of a Generic Specification for a sub-family of components and include a selection of test methods and severities, and preferred values for dimensions and characteristics peculiar to that sub-family. Quality assessment procedures to the sub-family are also included.

(d) Detail Specifications. Detail Specifications refer to Sectional Specifications and contain all information necessary to completely describe a given component or range of components, and to ensure conformance thereof with the requirements for quality assessment.

There is a somewhat unique aspect of the IECQ-System specification structure. It is that there are two options available for the preparation of Detail Specifications. The first option, is that Detail Specifications may be prepared by a recognized standard writing body, such as an IEC Technical Committee and are published by the IEC in the same manner as are the Basic, Generic and prepared by a National Standards Organization, such as EIA, or by a component manufacturer, from a Blank Detail Specification or from instructions for the preparation of Detail Specifications.

A Blank Detail Specification is as the title implies. It is a specification that follows a structured format and fixed language and requirements, but leaving certain performance and mechanical requirements needed to characterize the manufacturer's product.

The use of the Blank Detail Specification concept allows different manufacturers to meet the general performance requirements, manufacturer approval requirements, quality assessment requirements, and quality conformance inspection requirements through listing the specific performance values and a mechanical description that define or characterize his own electronic component in the "blanks", thus converting the document to a complete Detail Specification.

When the IEC Technical Committee or the National Standards Organization prepares a Detail Specification, it will include either fixed performance requirements or those requirements with clearly defined limits and this type of Detail Specification will contain instructions for part numbering and products from different manufacturers and may carry the same part number provided in fact that they meet all the requirements of the Detail Specification. A Detail Specification prepared by an approved manufacturer from a Blank Detail Specification does not result in an EIA standard part and will carry the manufacturer's part number and other manufacturer's identification.

It should be pointed out that EIA standards developed for use outside the EICQ-System, but following the IECQ-System specification structures, are not intended to comply in all respects with the IECQ-System specification format and content in the following areas: (1) EIA specifications carry the identification of an EIA standard and not the IECQ-System specification numbers; (2) EIA specifications reference U.S. and not IEC Basic Specifications; (3) EIA specifications allow a manufacturer to self-certify that he has met the requirements for manufacturer approval of initial test data (in the IECQ-System a third party National Supervising Inspectorate performs this function); and (4) follow-on surveillance of manufacturer quality conformance inspections and audits of the delivered product are not carried on by outside parties as it is done in the

IECQ-System unless the buyer of the component wishes to conduct such activities.

The use of Blank Detail Specifications by a manufacturer to produce a Detail Specification that characterizes his own product provides partial standardization in that standardized test procedures, manufacturer approval procedures, and quality conformance inspection procedures are required. This approach to partial standardization of an electronic component may be viewed as the first step toward the future development of a Detail Specification for that component that calls out definitive electrical performance and mechanical requirements.

EIA standards produced following the IECQ-System Specification Structures, as outlined above, are easily converted to U.S. positions for introduction into the IECQ-System.

DRAFT

PROPOSED STANDARD FOR THE SHIPBOARD USE OF FIBRE OPTIC SPLICES (MECHANICAL)

NOTICE

This standard was formulated for the purpose of eliminating misunderstandings or confusion between manufacturers and buyers with respect to product performance requirements.

It applies to mechanical splices in fiber optic cable intended for use in marine applications.

This proposed standard is based on EIA-475.

This Standard is recommended without regard to patents or other proprietary rights. No liability is assumed in regard to such rights, nor is there any obligation to parties adopting the Standard.

FOCAL MARINE LIMITED
1378 Bedford Highway
Bedford, Nova Scotia

April, 1985.
Updated March, 1987.

Proposed Standard
for the Shipboard Use of
Fibre Optic Splices (Mechanical)

1.0 Scope

Mechanical splices covered by this Proposed Standard include both permanent and separable devices used to connect optical waveguides.

Interconnecting device types may be for single, duplex or multifiber cables. The cables may contain glass, silica or plastic fibers as per the Proposed Standard for the shipboard use of optical fibre waveguide.

2.0 Applicable Documents

EIA-455-3
EIA-455-5
EIA-455-6
EIA-455-11
EIA-455-12
EIA-455-13
EIA-455-14
EIA-455-16
EIA-455-34
EIA-475

3.0 Classification

3.1 Type

A. Elastomeric construction providing mechanical strain relief

B. Composite, i.e. glass, elastomeric and/or metallic in construction providing mechanical strain relief.

3.2 Class

1. Capable of being permanently affixed.

2. Capable of being re-enterable.

4.0 Definitions

4.1 Splicing Components

Components that provide alignment and fiber protection.

4.2 Elastomerics

Non-metallic components that exhibit elastic properties.

4.3 Index Matched Fluids

Materials used in intimate contact between termini of a junction to reduce optical power loss.

5.0 Design Requirements

5.1 Materials

All metallic material shall be marine grade quality. Non-metallic materials shall be suitable for the intended marine application.

5.2 Design and Construction

5.2.1 Mechanical splices shall be of the design and construction required to withstand all specified conditions of mechanical and environmental testing for the individual application.

5.2.2 Mechanical splices shall be affixed to a solid structure by means of stainless steel. brass or bronze hardware or approved epoxy adhesive.

5.2.3 Unless otherwise specified the mechanical splice shall be sealed from re-entry and moisture ingress.

5.2.4 All splicing components of the mechanical splice shall be composed of materials with similar thermal expansion characteristics. Metallic components shall be of a specified stainless steel, brass or marine bronze.

5.2.5 When adhesives are required for terminating the optical fiber or for sealing or fastening the mechanical splice, the adhesive shall be fully specified.

5.2.6 All mechanical splice materials shall resist fungus growth.

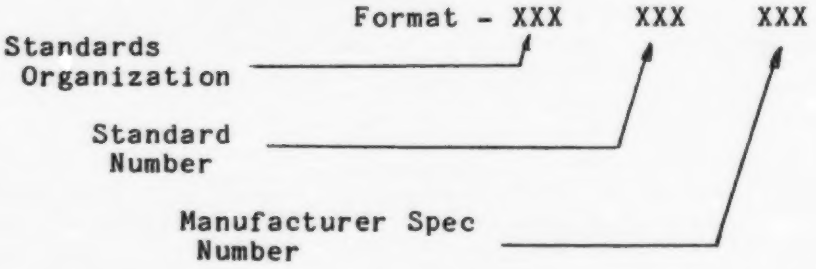
5.2.7 The mechanical splice assembly shall provide cable strain relief to prevent degradation of optical performance or fiber damage by (1) cable flexing or twisting at or near the splice, or (2) cable pull- out by tensile forces.

5.2.8 Splicing procedures including fiber/cable preparation shall be specified in the form of a step by step instruction as provided by the splice manufacturer.

5.2.9 Index matching fluid, when required, shall be specified including its index of refraction and its ability to remain clear and fluid at low tempteratures.

5.2.10 The physical dimensions for a single fiber splice shall not exceed:
Length: 100 mm
Width: 20 mm
Height: 15 mm

5.2.11 Each mechanical splice covered by the standard and outlined in the detailed specifications shall be assigned a discrete part number in the following format:



Any required markings which cannot be applied to the splice shall be applied to the unit package.

6.0 Performance Requirements

6.1 Insertion Loss

When tested in accordance with EIA-455-34, the splice insertion loss shall not exceed 1.5 dB for a test wavelength of 850 nm and .30 dB for a test wavelength of 1300 nm.

6.2 Temperature Cycling

When temperature cycled in accordance with EIA-455-3 as modified in Appendix A, the insertion loss and test method shall be as specified in section 6.1 herein.

There shall be no damage detrimental to operation and fiber protection of the splice assembly.

6.3 Cable Protection

When tested in accordance with EIA-455-6 there shall be no evidence of structural damage detrimental to operation and the insertion loss and test method shall be as specified in section 6.1.

Tensile loads shall be 100 N. Loads shall be applied for 1 min.

6.4 Vibration

When tested in accordance with EIA-455-11, there shall be no evidence of cracking, breaking or loosening of parts. Insertion loss and test method shall be as specified in section 6.1 herein.

Measurements shall be taken before and after testing.

6.5 Shock

When tested in accordance to EIA-455-14, there shall be no evidence of cracking, breaking or loosening of parts. Insertion loss and test method shall be as specified in section 6.1 herein. Measurements shall be taken after the shock test.

6.6 Humidity

When tested in accordance to EIA-455-5, the splice shall show no deterioration which will adversely affect performance. The insertion loss and test method shall be as specified in section 6.1 herein. Measurements are to be taken during and after testing. In addition to the requirements of EIA-455-5, the conditions as specified in EIA-475 section 7.7.13 shall also be complied with.

6.7 Salt Spray

When tested in accordance to EIA-455-16, the splice shall show no signs of pitting, cracking or deterioration of components or finishes or both. The insertion loss and test method shall be as specified in section 6.1 herein.

6.8 Fluid Immersion

When tested in accordance to EIA-455-12, there shall be no deterioration which will adversely affect performance. Insertion losses and test method shall be as specified in section 6.1 herein. Fluid types, number of cycles and fluid temperature shall be as specified in future specifications. Measurements shall be taken after testing.

6.9 Post Test Examination

Post test examination shall be conducted in accordance with the terms specified in EIA-455-13. The splice shall have any markings legible; there shall be no cracks in the materials used; no corrosion; no opening of seals, no cracking or crazing or delamination of components or finishes and no leaking of fluid materials.

These conditions shall be judged on their effect on the continued successful operation of the cable splice and the ability of the splice to meet the requirements of the individual application.

Appendix A

Proposed Modification
to Temperature Cycling
per EIA-455-3

Number of Cycles

One cycle consists of steps 1 through 3 of the applicable test condition. Specimens shall not be subjected to forced circulating air while being transferred from one chamber to another. Direct heat conduction to the specimen should be minimized.

Table 1
Temperature Cycling

	Test Condition	Number of Cycles
Step	A	5
	A-1	25
	A-2	50
	A-3	100

	Temperature (zero degrees C)	Time (Minutes)
	Hot Cycle	Cold Cycle
1	20 degrees C	20 degrees C
2	150 degrees C	-50 degrees C
3	20 degrees C	20 degrees C

Exposure Time at Temperature Extremes

The connector samples shall be subjected to the temperature extremes for one of the durations of Table 2 in EIA-455-3. The duration of the test and length of exposure are standardized for a given mass of the test item. This approach allows the connector to reach thermal stability at the temperature of the test chamber while keeping the testing time to a minimum.

Temperature Cycles

In order to simulate all reasonable temperature cycles, tests shall be done on both a hot cycle and a cold cycle. It is not necessary that a single splice should perform equally well in both the hot cycle and the cold cycle.

PROPOSED STANDARD FOR THE SHIPBOARD APPLICATIONS OF FIBRE OPTIC ENCLOSURES

NOTICE

The purpose of this standard is to recommend guidelines for the selection and use of enclosures for fibre optic components used in shipboard applications. It addresses only those areas of concern which are peculiar to fibre optics. In all other aspects, the standards for enclosures shall be as given in the Transport Canada publication TP-127E and its reference documents. The existence of this standard for the shipboard use of fibre optic enclosures does not preclude the use of products not conforming to the standard.

The standard is recommended without regard to patents on other proprietary rights. No liability is assumed in regard to such rights, nor is there any obligation to parties adopting the standard.

FOCAL MARINE LIMITED
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April, 1985.
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Reference Documents

1. IEEE Std 45-1983, IEEE Recommended Practice for Electric Installation on Shipboard
2. Transport Canada TP127E, Ship Safety Electrical Standards
3. ANSI Z136.1-1980, American National Standard for the Safe Use of Lasers

1.0 Definition of Enclosures

1.1 For the purpose of this standard, the definitions of enclosures shall be as given on the most recent edition of the Institute of Electrical and Electronic Engineers Standard 45, "IEEE Recommended Practice for Electric Installations on Shipboard."

2.0 Laser Sources

2.1 Enclosures which contain optical components that are part of a fibre optic system which uses, as a source of optical power, a laser device, shall be clearly identified by marking them as a source of laser light emission in accordance with ANSI Z136.1-1980, "American National Standard for the Safe Use of Lasers."

3.0 Grounding

3.1 Enclosures which contain, in addition to fibre optic elements, electrical or electronic components, shall conform to the standards for electrical and electronic enclosures as well as this Standard on fibre optic enclosures.

3.2 Armoured cables which are led to fibre optic enclosures, made of electrically conductive material, shall have their armour grounded to the enclosure.

3.3 Enclosures to which armour is to be grounded shall be of metal construction and shall be grounded to the ship's electrical system.

3.4 All ground connections shall be of the low impedance type.

4.0 Mounting of Enclosures

4.1 Enclosures should not be mounted in areas where they will be exposed to excessive shock, vibration, temperature or humidity.

4.2 Enclosures should be located so that they are readily accessible.

4.3 Adequate means shall be provided within the enclosure for mounting components.

4.4 Enclosures should be located so as to permit connection to auxiliary equipment with the shortest possible lead lengths.

4.5 Access panels shall either be completely removable or hinged. In the case of hinged panels, a means shall be provided for securing the panel in the open position.

5.0 Size of Enclosures

5.1 Enclosures shall be sufficiently large to contain the elements which it is intended to contain, and allow access to them.

5.2 Enclosures shall provide sufficient space to allow for storage of several loops of each cable entering the enclosure and be of such size and shape that the fibre or cable is not subject to bends at less than the minimum bend radius.

6.0 Splice Enclosures

6.1 Splice enclosures shall provide a means for storing and retaining cable slack, end splices and pigtail slack.

6.2 Means shall be provided for storage of sufficient pigtail slack so that the splicing can be done at some distance from the mounted enclosure.

6.3 Means shall be provided to maintain no less than the minimum bend radius of the cable in the case of cable slack storage or the minimum bend radius of the fibre in the case of pigtail slack storage, whichever is greater.

6.4 Means shall be provided for organizing the splices so that the installation is given a neat, orderly appearance.

6.5 Means shall be provided for easy identification of each splice.

6.6 Means shall be provided for retaining and providing strain relief to each splice. These means shall be compatible with the type of splice used.

6.7 The means of splice organization shall be such that each splice can be accessed without interrupting others.

6.8 Where splices are organized on hinged, sliding or removable trays, means shall be provided for securing each tray in its normal position as well as in its access position.

7.0 Ventilation

7.1 Ventilation is not normally required due to the low level of heat generated by fibre optic devices; hence enclosures can be watertight.

7.2 Should ventilation be required, the enclosures must be drip-proof. Filters are required on air intake vents to remove particulates that could affect optical surfaces.

PROPOSED STANDARD FOR SERVICE INSTRUMENTS TO BE USED WITH SHIPBOARD FIBRE OPTIC SYSTEMS

NOTICE

The purpose of this Proposed Standard is to recommend guidelines for the selection and use of tools and instruments for use in association with shipboard fibre optic systems. Some of the equipment required to install and service fibre optic systems is not unique to such systems and is used onboard ships for other purposes. This Proposed Standard does not attempt to further classify them, but rather concerns itself with items which are peculiar to fibre optics. However, the existence of this Standard for service instruments to be used with shipboard fibre optic systems does not preclude the use of products not conforming to the Standard.

The Standard is recommended without regard to patents or other proprietary rights. No liability is assumed in regard to such rights, nor is there any obligation to parties adopting the Standard.

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1.0 Definitions

For the purpose of this Standard, the following definitions apply:

1.1 Equipment

Items which are used to provide a service in the installation, operation or servicing of a fibre optic system and which require a power source other than or in addition to manually applied energy supplied by the operator.

1.2 Handtools

Items which are operated manually and receive no power from external or internal sources other than that supplied by the operator.

1.3 Instruments

Items which are used to monitor or analyze the operation of a fibre optic system.

2.0 Reference Documents

2.1 TP 127E, Transport Canada, Ship Safety Electrical Standards

2.2 IEEE STD 45, IEEE Recommended Practice for Electric Installations on Shipboard

2.3 Proposed Standard for Shipboard Applications of Fibre Optic Enclosures

2.4 Transport Canada, CRC Ch. 1,4,6 and 7, Safe Working Practice Regulations.

3.0 General Requirements

3.1 Handtools

3.1.1 Types of Handtools

Handtools used to service and/or install marine fibre optic systems may include but are not restricted to the following:

- cable pulling rope
- cable pulling grip
- cable pulling swivel
- cable tension scale
- torque wrench
- connector polishing equipment
- cable stripping tools
- fibre stripping tools
- fibre cleavers
- temporary terminating kits for fibre
- magnifying glass
- scissors
- scalpel
- crimping tool.

3.1.2 Materials

Materials used in the construction of handtools should enable the tools to meet the performance requirements.

Aluminum and steel parts should be corrosion resistant for use onboard marine vessels. The materials used in the construction of handtools should be such that the end product is durable in that it does not break, crack, chip or be damaged in any manner which would impair the service function of the tool when subject to normal work conditions.

3.1.3 Design and Construction

Tools should be designed so that they are capable of offering many years of service when subject to normal service conditions.

Unless required to be otherwise because of service requirements, all tool tips and edges should have a smooth finish and rounded edges.

Tools should be constructed so that they can be readily disassembled for cleaning and servicing. Those parts of tools which are subject to wear should be available as replacement parts.

Tools should be so designed and constructed that they can, with periodic maintenance, match the life expectancy of the system which they will be servicing.

All tools should be clearly and durably marked as to the name of the manufacturer and the part number.

Tools should be fabricated or constructed in accordance with the best practice to produce an item free from all defects which would effect proper functioning in service. Particular attention should be given to freedom from chips, dirt, grit and other foreign material; also to freedom from defects, burrs, sharp edges, corners and points.

When a tool is supplied with interchangeable parts to accommodate different sizes or types of materials, the parts should be clearly and durable marked.

3.1.4 Packaging

When a tool is supplied with interchangeable parts, a suitable case should be provided to contain, protect and organize the tool and the parts. The case should also contain any tools or supplies required to service the tool.

3.1.5 Operation

All handtools should be supplied with instructions for their proper use and maintenance as well as the information necessary for ordering replacement parts.

3.2 Instrumentation and Equipment

3.2.1 Types of Instrumentation and Equipment

Instrumentation and equipment used to service and/or install marine fibre optic systems may include but are not restricted to the following:

microscope
optical time domain reflectometer
optical signal generator
optical power meter
fusion splicer
heat gun
UV gun.

3.2.2 Power Requirements

Power requirements vary according to the function which is required from the equipment. In general, equipment chosen for use onboard a vessel should be able to utilize the normally available power supply aboard the vessel.

Wherever possible, for the sake of portability, equipment power requirements should be provided by a self contained battery pack. The battery pack should be rechargeable from the ship's power supply and the equipment should be capable of operating from the ship's power supply equally well as from the battery pack.

The equipment should be protected from normal voltage and cyclic variations that are associated with the ship's generating system as well as the normal range of transients which can be expected in the distribution system.

Notwithstanding the requirements expressed herein, electrical power requirements should be in accordance with the requirements as given in TP127E, Ship Safety Electrical Standards, and IEEE STD 45, IEEE Recommended Practice for Electric Installations on Shipboard.

3.2.3 Enclosures

3.2.3.1 Fixed

Equipment and instruments used to install and service fibre optic systems should, if to be permanently mounted, be enclosed in accordance with the Proposed Standard for Marine Application of Fibre Optic Enclosures.

3.2.3.2 Portable

Portable equipment and instruments should be suitably enclosed for use onboard ships. Enclosures should be rugged and impact resistant. The materials used for enclosures should be compatible and corrosion resistant. As a minimum requirement enclosures used for portable items should be splash proof as specified in IEEE STD 45.

3.2.3.3 Hazardous Areas

Equipment and instruments which are to be used or located in hazardous areas should be certified for use in such areas and used in accordance with the guidelines outlined in the Transport Canada publication CRC Ch 1,4,6 and 7, Safe Working Practice Regulations.

3.2.3.4 Storage

Means should be provided for storage of portable equipment when not in use. Consideration should be given to preventing the equipment from moving as the result of the ship's motion. Also, controls and displays which are sensitive to damage should be provided with protective covers. The operating instructions may specify other precautions, such as the inclusion of a desiccant package, which may be required for extended storage periods.

3.2.4 Operation

All equipment and instrumentation should be supplied with the following:

(a) specification sheets
(b) detailed operating instructions
(c) instructions on how and where to obtain service
(d) any special tools required for normal operation.